



## **Mere end struktur - moderne anvendelse af højopløselig airborne geofysik i hydrologiske modeller**

**Vilhelmsen, Troels; Marker, Pernille Aabye; Foged, Nikolaj; Wernberg, Thomas; Høyer Christensen, Anne-Sophie; Bauer-Gottwein, Peter; Christensen, Steen; Auken, Esben**

*Publication date:*  
2015

*Document Version*  
Publisher's PDF, also known as Version of record

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*Citation (APA):*  
Vilhelmsen, T. (Author), Marker, P. A. (Author), Foged, N. (Author), Wernberg, T. (Author), Høyer Christensen, A-S. (Author), Bauer-Gottwein, P. (Author), Christensen, S. (Author), & Auken, E. (Author). (2015). Mere end struktur - moderne anvendelse af højopløselig airborne geofysik i hydrologiske modeller. 2D/3D (physical products)

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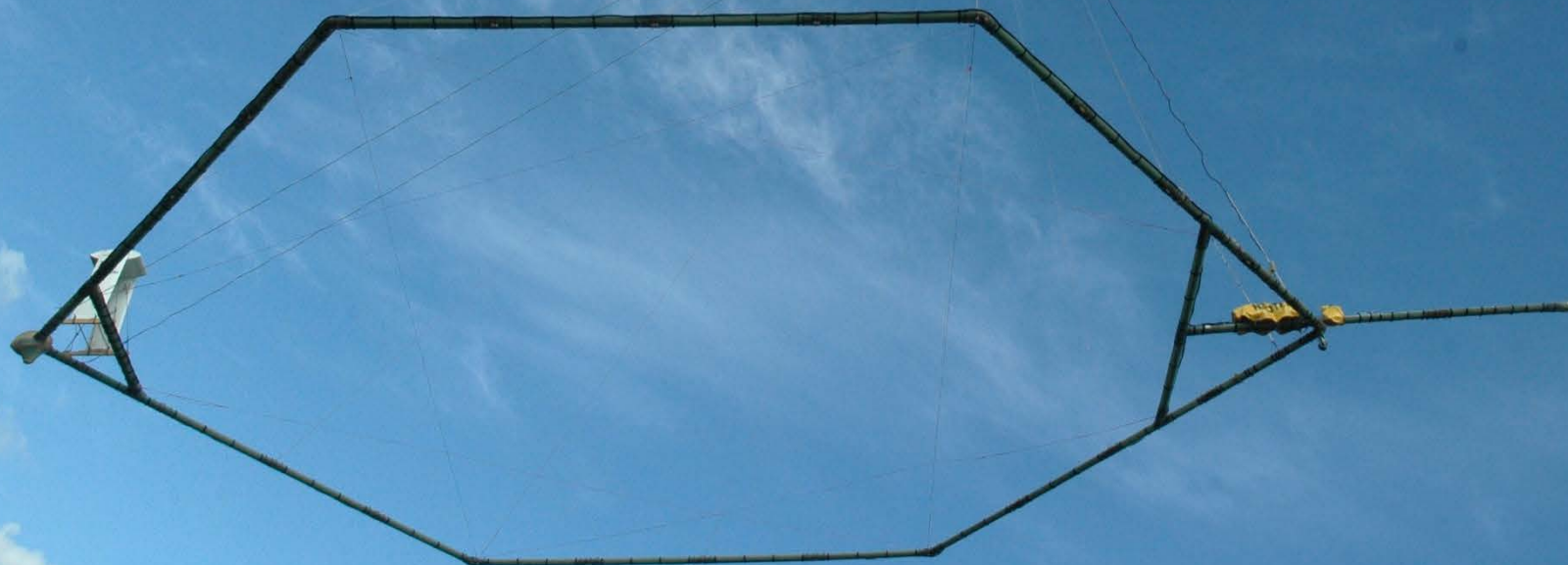
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# Mere end struktur

*- moderne anvendelse af højopløselig  
airborne geofysik i hydrologiske modeller*

Troels Vilhelmsen, AU; Pernille Marker, DTU; Nikolaj Foged, AU  
Thomas Wernberg, Alectia; Anne-Sophie Høyer Christensen, GEUS  
Peter Bauer-Gottwein, DTU; Steen Christensen, AU; Esben Auken, AU



# Strukturel usikkerhed...

## Capture zone, travel time, and solute-transport predictions using inverse modeling and different geological models

William G. Harrar · Torben Obel Sonnenborg ·  
Hans Jørgen Henriksen

WATER RESOURCES RESEARCH, VOL. 48, W06503, doi:10.1029/2011WR011149, 2012

ministes ont été utilisés pour définir les distributions de la  
conductivité hydraulique dans deux modèles d'écoulement  
en régime permanent qui ont été calibrés avec des  
estimations des charges et des écoulements de base faites  
par des techniques inverses. Les estimations optimisées

## Assessment of hydrological model predictive ability given multiple conceptual geological models

Dorte Seifert,<sup>1</sup> Torben O. Sonnenborg,<sup>2</sup> Jens Christian Refsgaard,<sup>2</sup> Anker L. Højberg,<sup>2</sup>  
and Lars Trolldborg<sup>2</sup>

## Use of alternative conceptual models to assess the impact of a buried valley on groundwater vulnerability

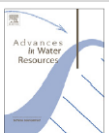
Dorte Seifert · Torben O. Sonnenborg ·  
Peter Scharling · Klaus Hinsby



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## Review of strategies for handling geological uncertainty in groundwater flow and transport modeling

Jens Christian Refsgaard<sup>a,\*</sup>, Steen Christensen<sup>b</sup>, Torben O. Sonnenborg<sup>a</sup>, Dorte Seifert<sup>c</sup>,  
Anker Lajer Højberg<sup>a</sup>, Lars Trolldborg<sup>a</sup>

<sup>a</sup> Geological Survey of Denmark and Greenland (GEUS), Øster Voldgade 10, DK-1350 Copenhagen K, Denmark

<sup>b</sup> Department of Earth Sciences, Aarhus University, Denmark

<sup>c</sup> ALECTIA, Denmark

# **Autogenerering af hydrostratigrafiske modeller fra SkyTEM data og boringsbeskrivelser**

**Kan denne metoder anvendes til evaluering af strukturel usikkerhed**



# CF-Resistivity clustering

## Input

- Resistivity model
- Borehole lithology



**Clay fraction**

## Input

- Clay fraction model
- Resistivity model



**3D cluster model**

## Input

- Cluster model
- Potential head
- Stream discharge

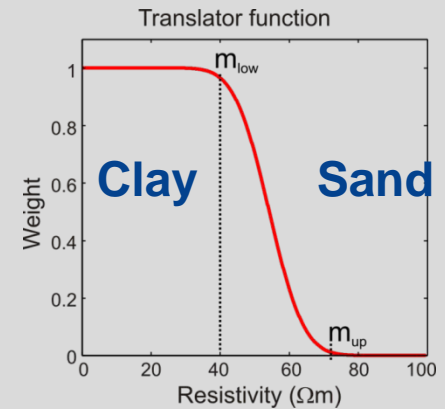
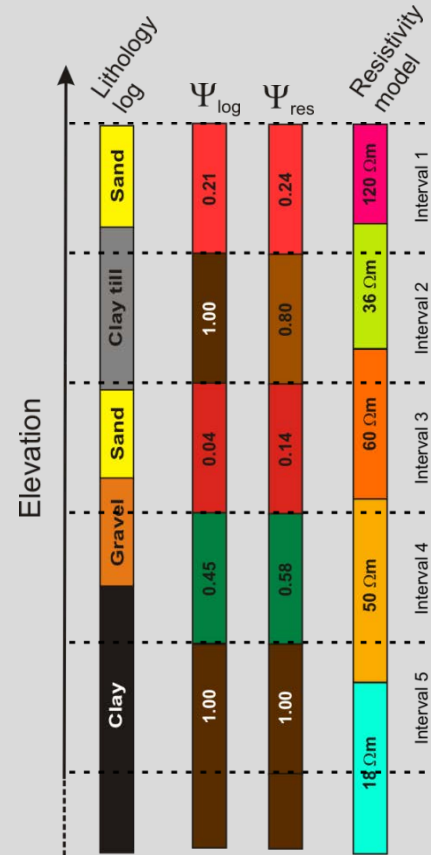
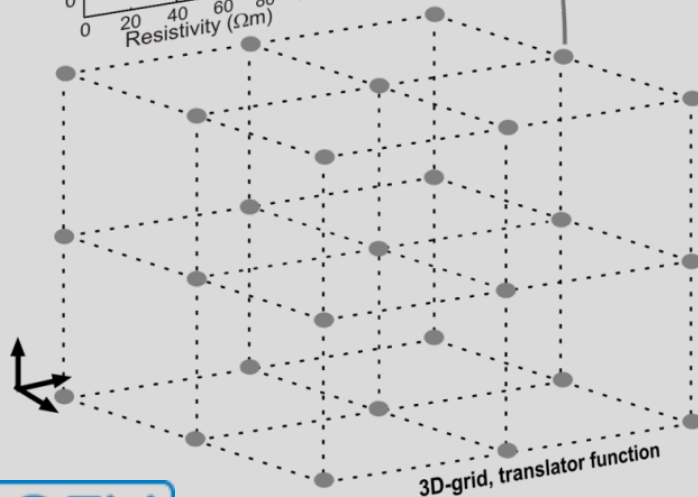
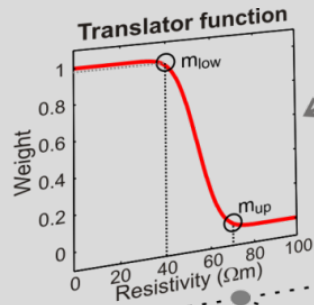


**Hydrological model calibration**

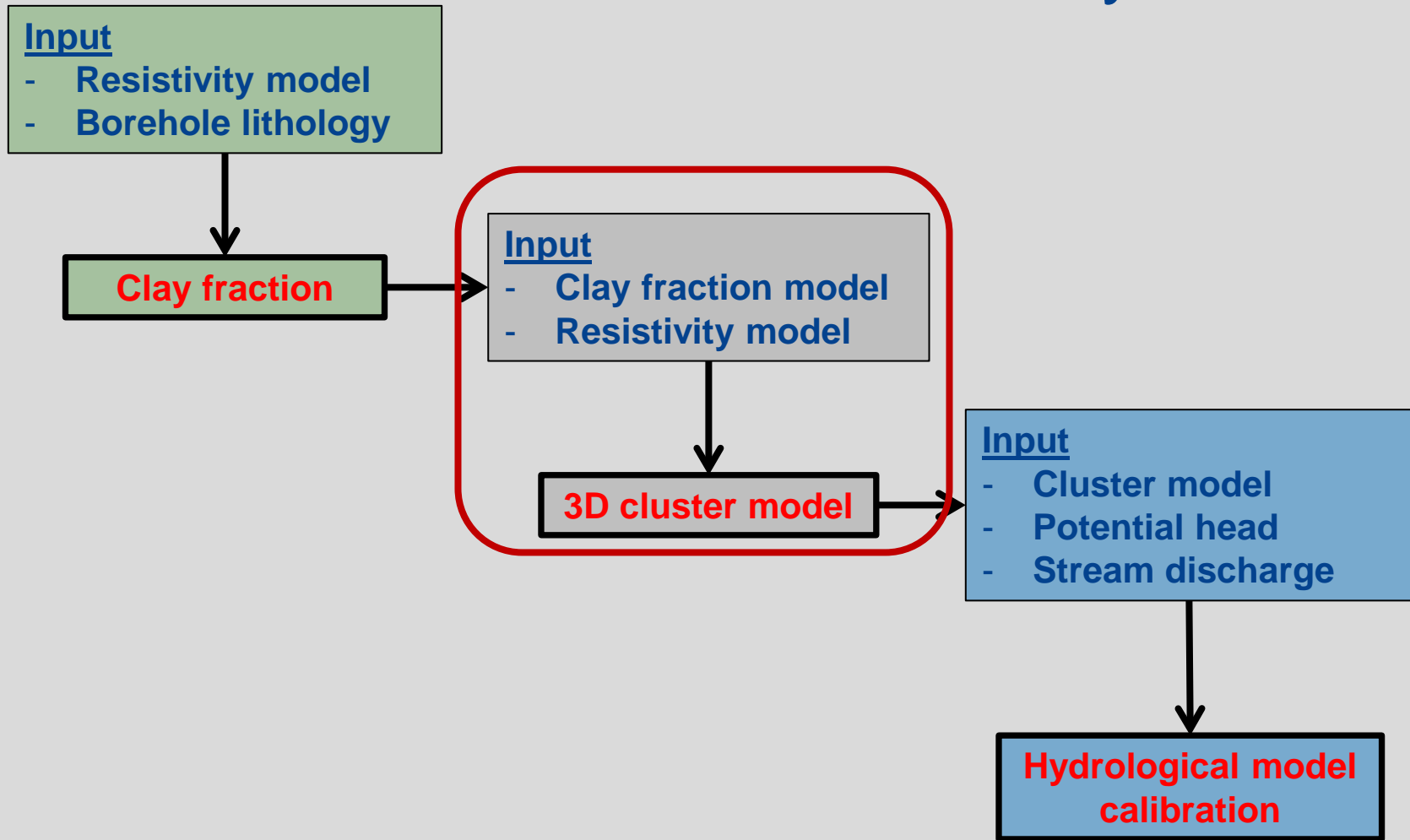


# Clay fraction (CF) concept

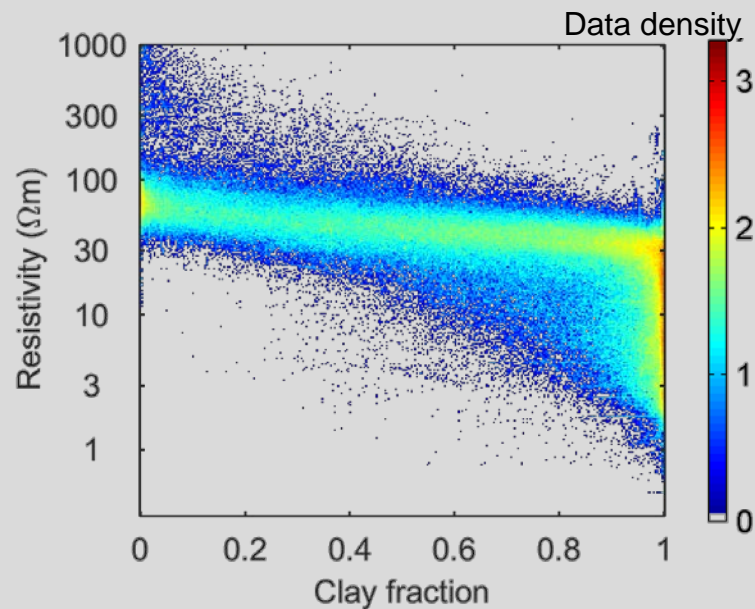
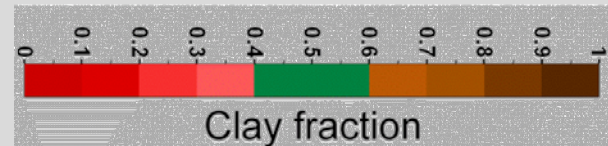
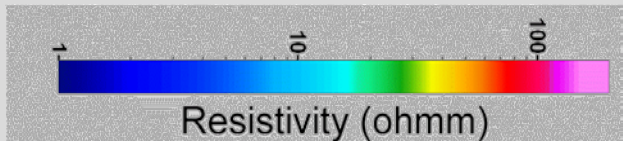
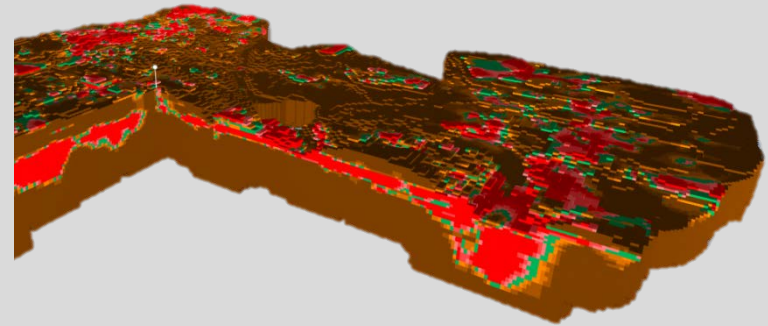
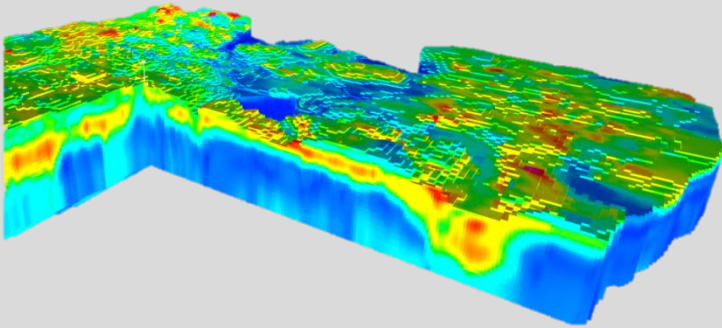
Translate resistivity to clay/sand using lithological logs



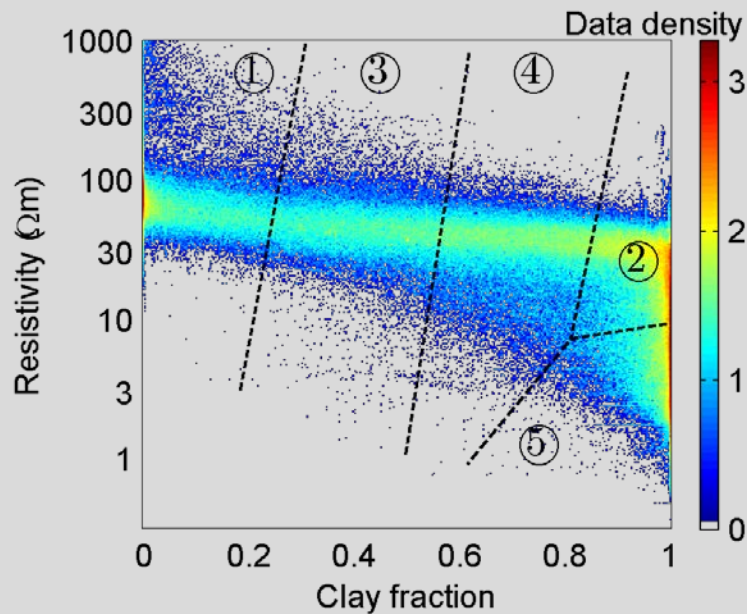
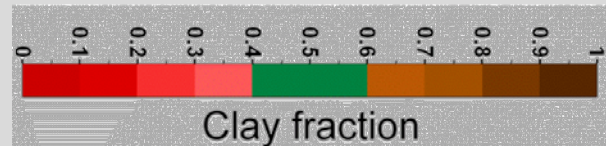
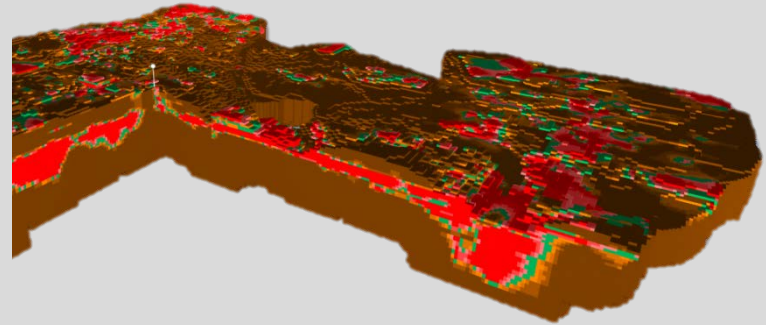
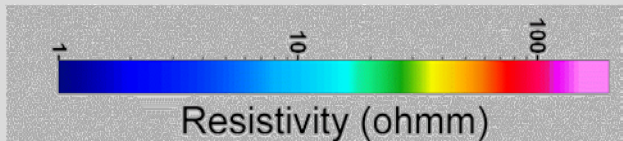
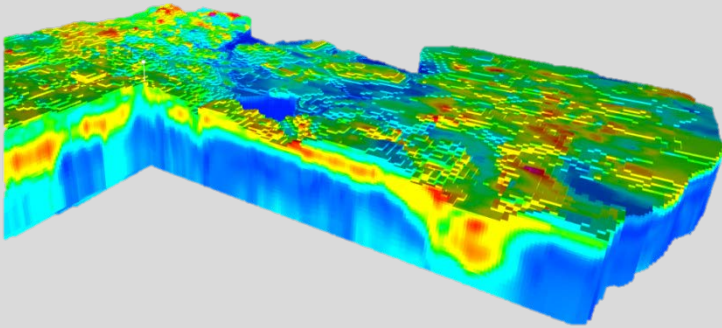
# CF-Resistivity clustering



# 3D cluster model

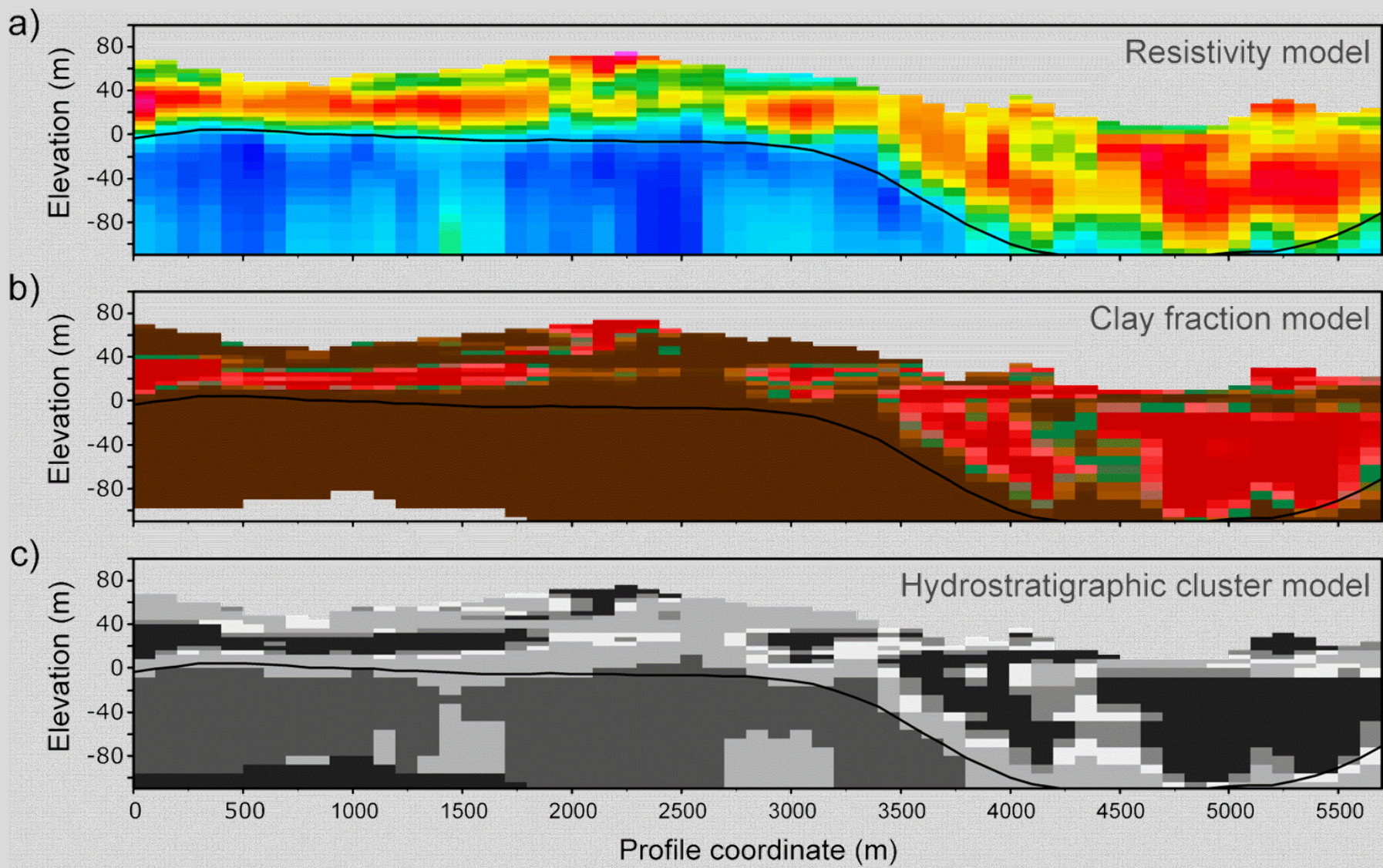


# 3D cluster model

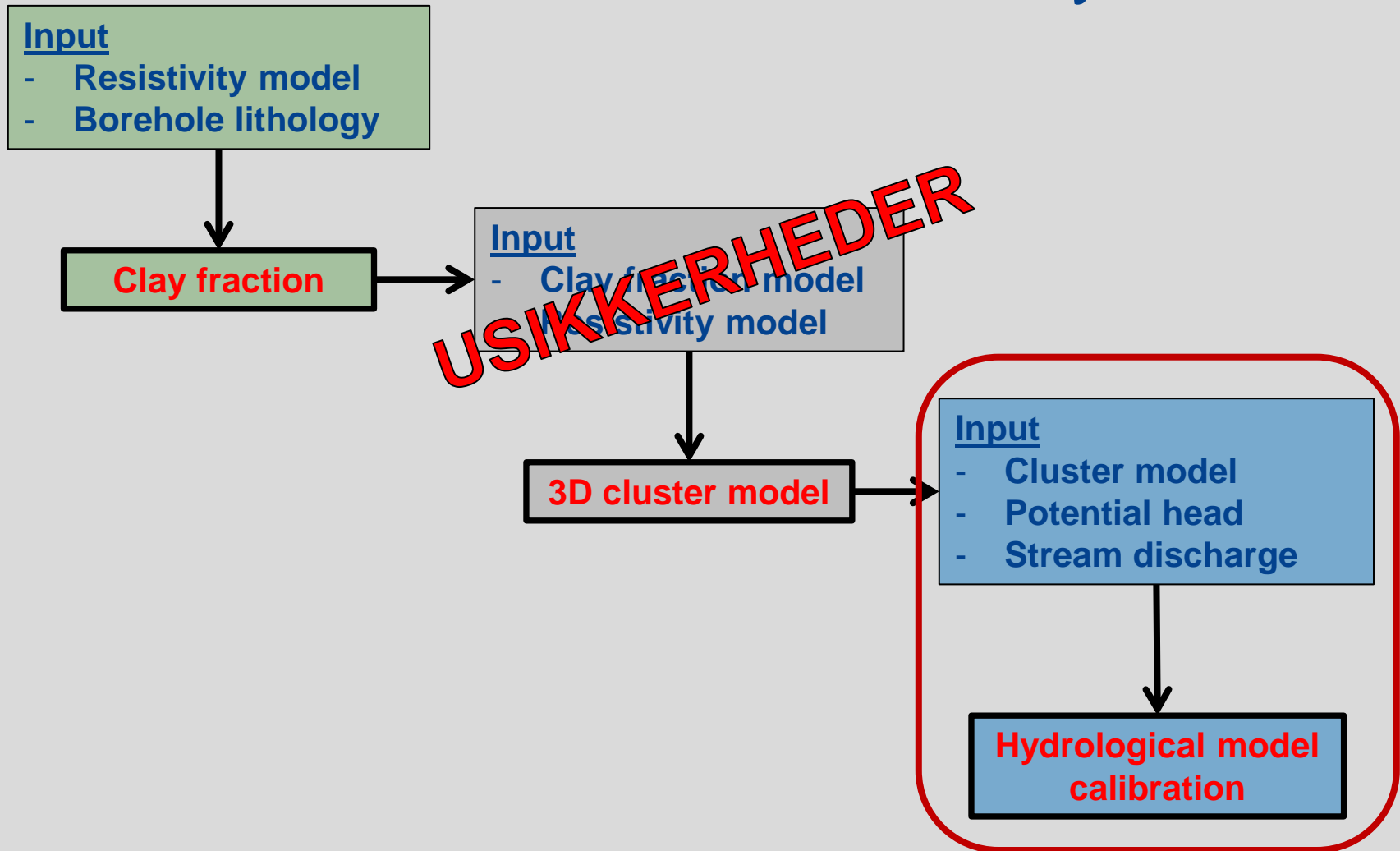


**5 clusters udvalgt vha.  
k-means**

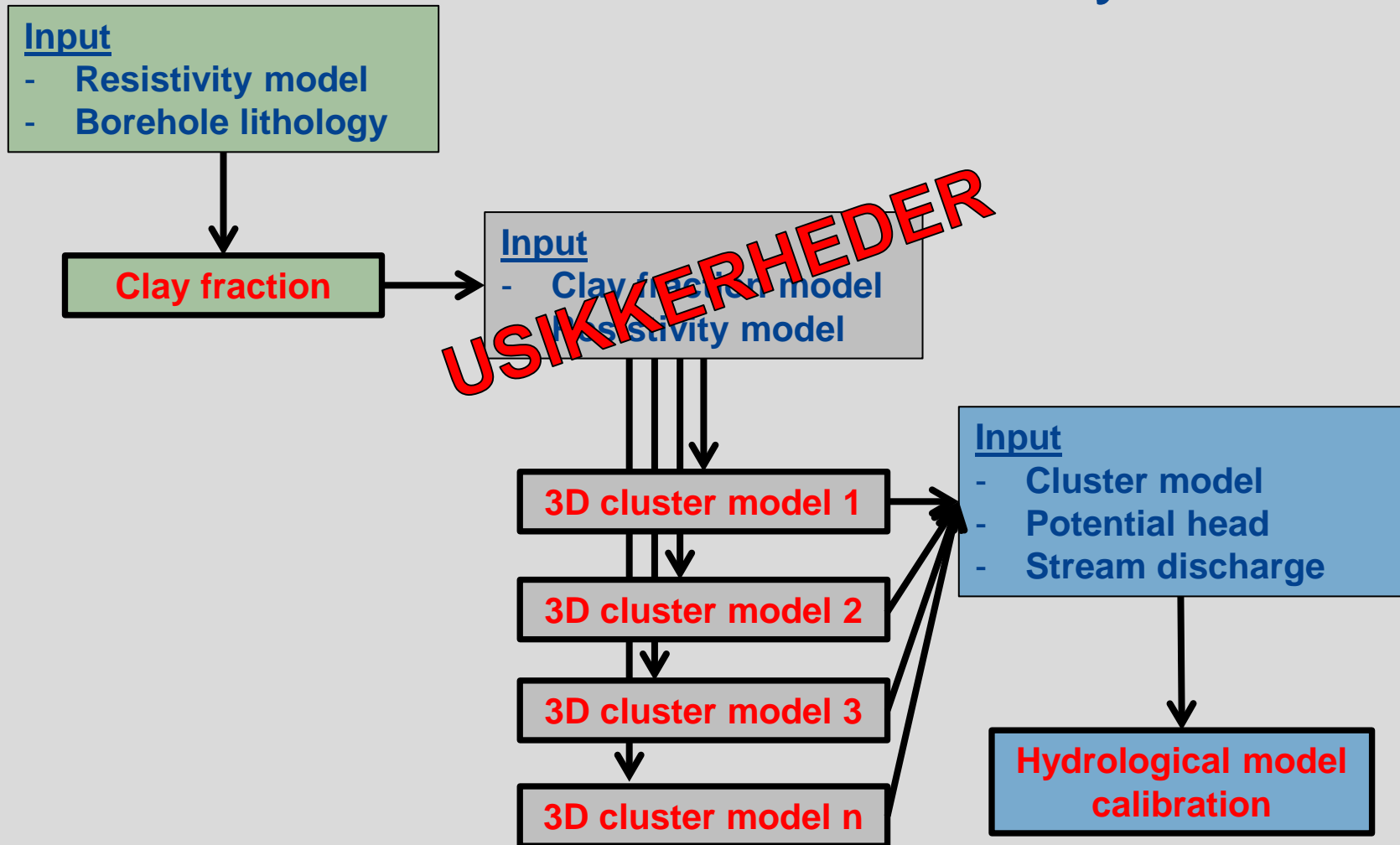




# CF-Resistivity clustering



# CF-Resistivity clustering



USIKKERHEDER



# Håndtering af usikkerheder på input

- Perturber resistivitet og CF med usikkerheder på felter

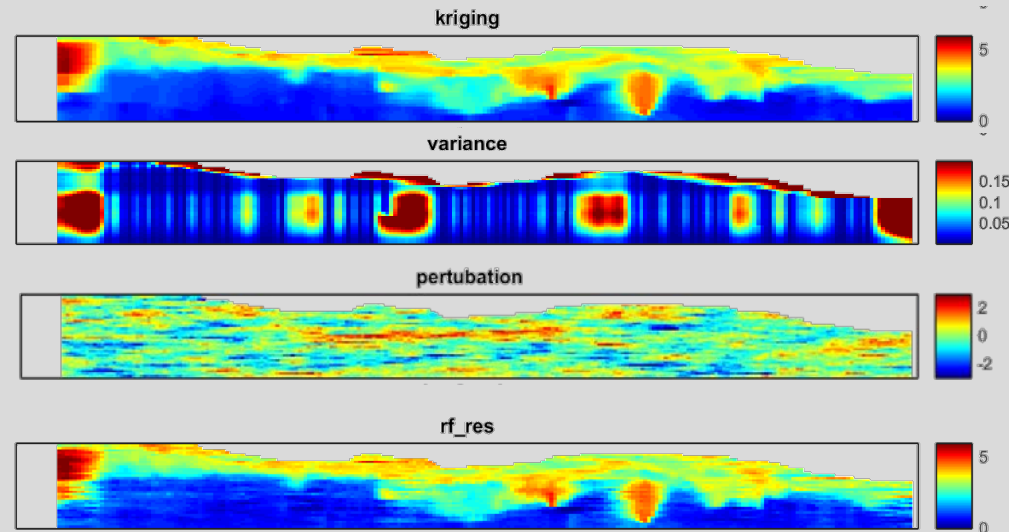
$$X(x) = X'(x) * \sigma(x) + \mu(x)$$

$\mu$ : mean

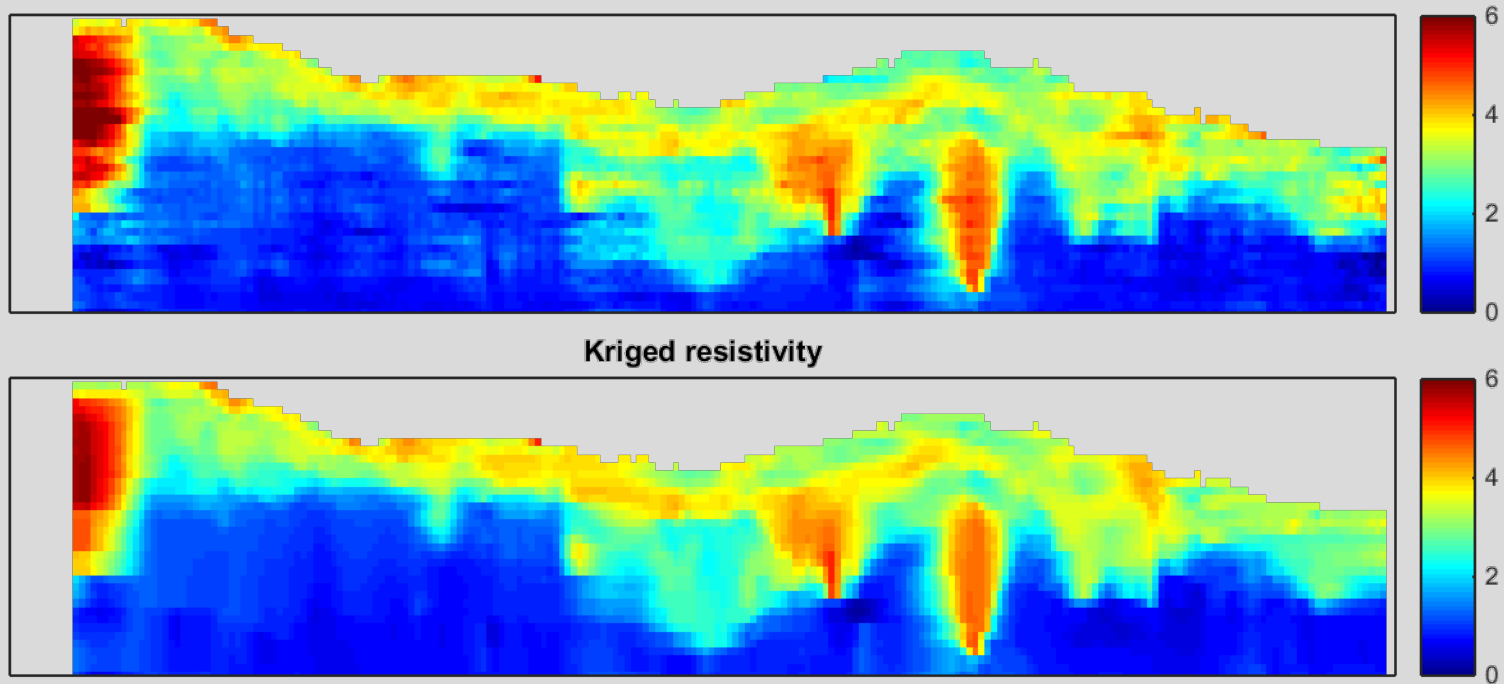
$\sigma$ : standard deviation

$X'$ : stationary random field

$X$ : non-stationary  
perturbed field

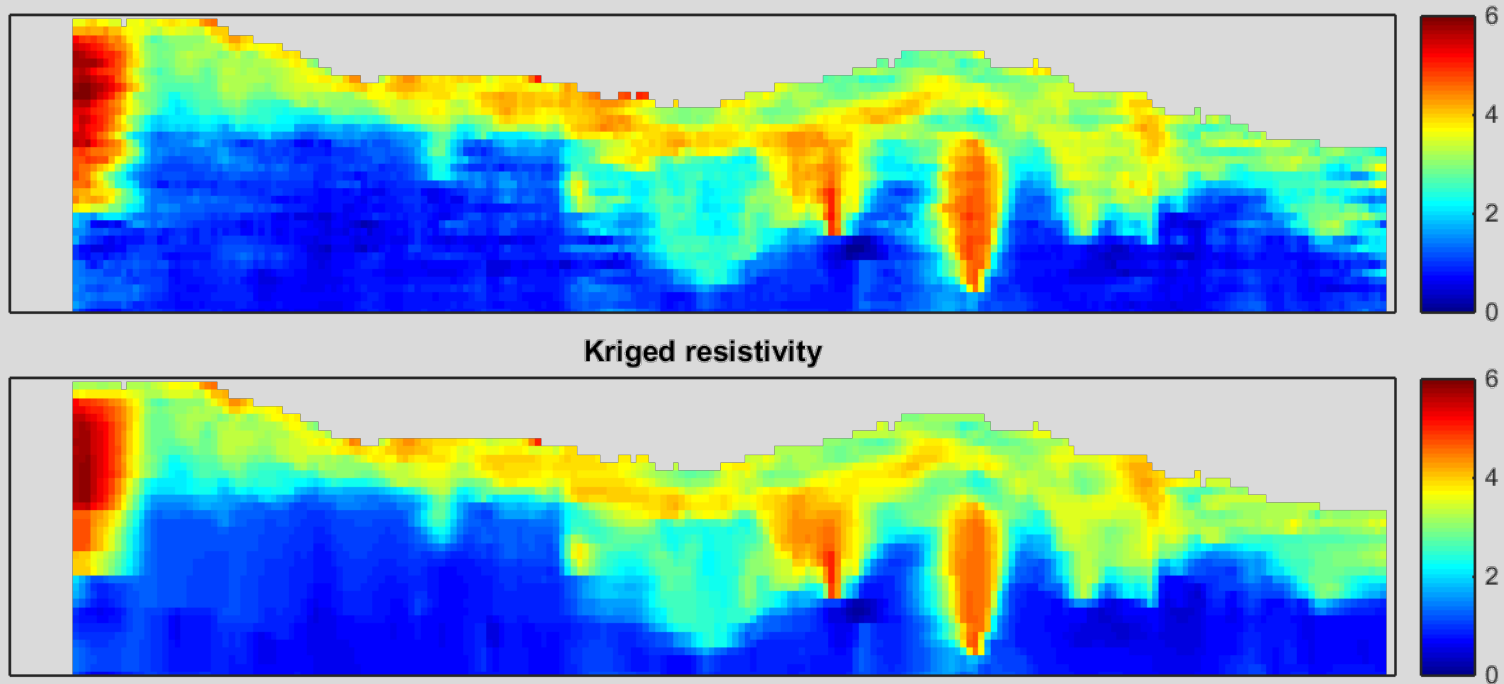


# Usikkerheder i resistivitet

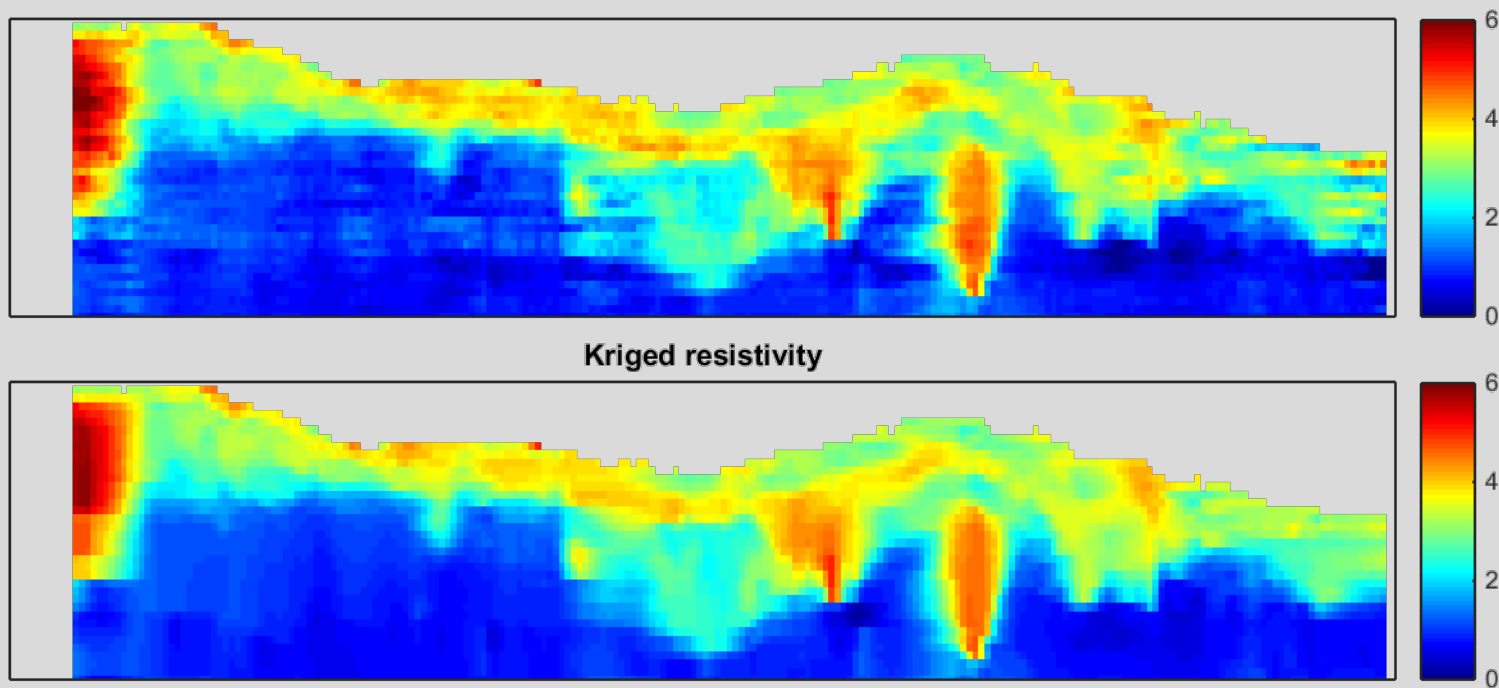




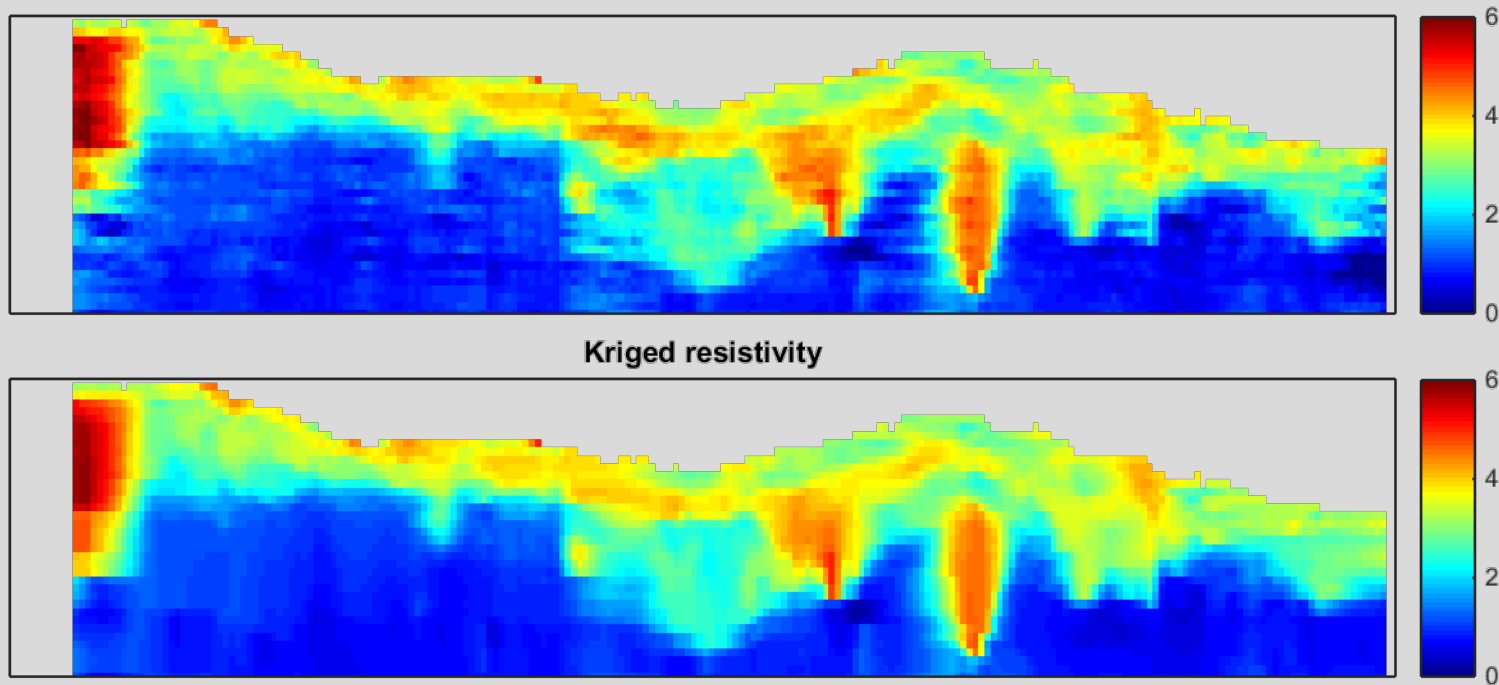
# Usikkerheder i resistivitet



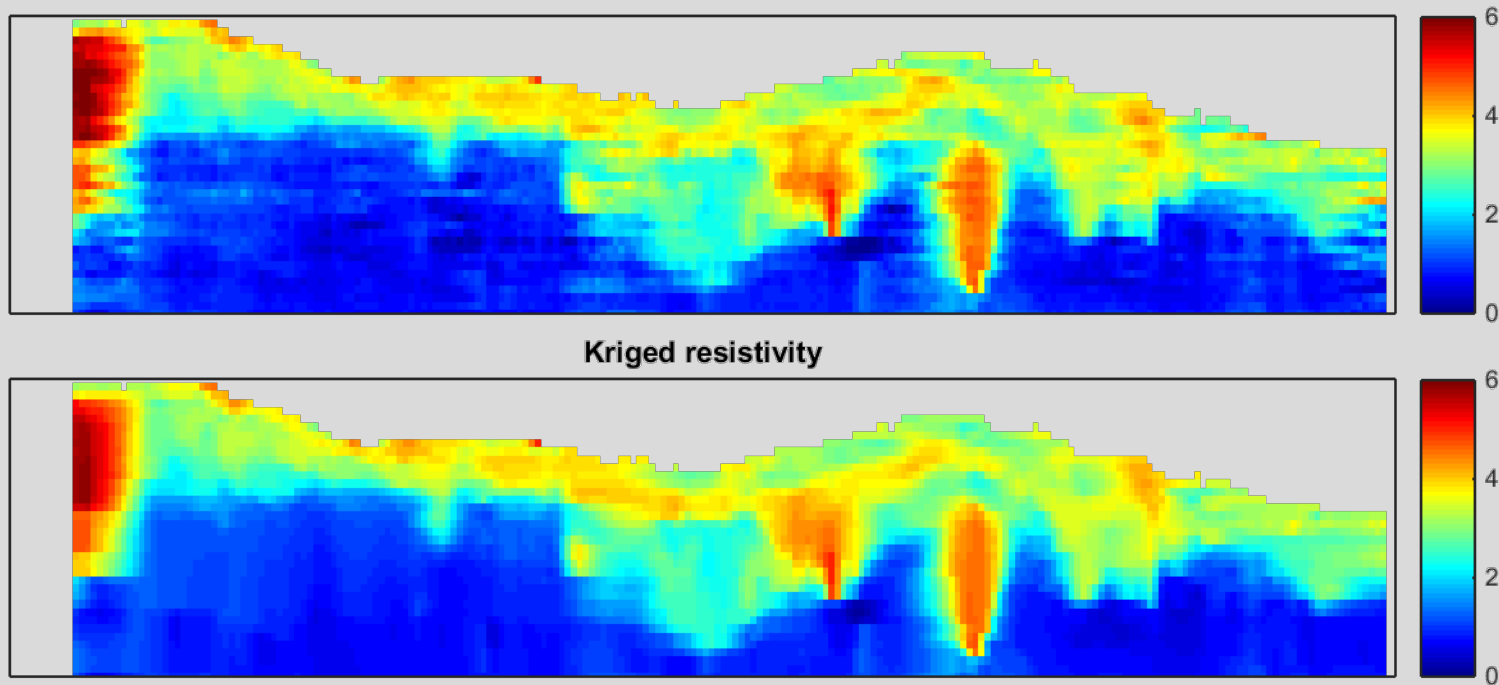
# Usikkerheder i resistivitet



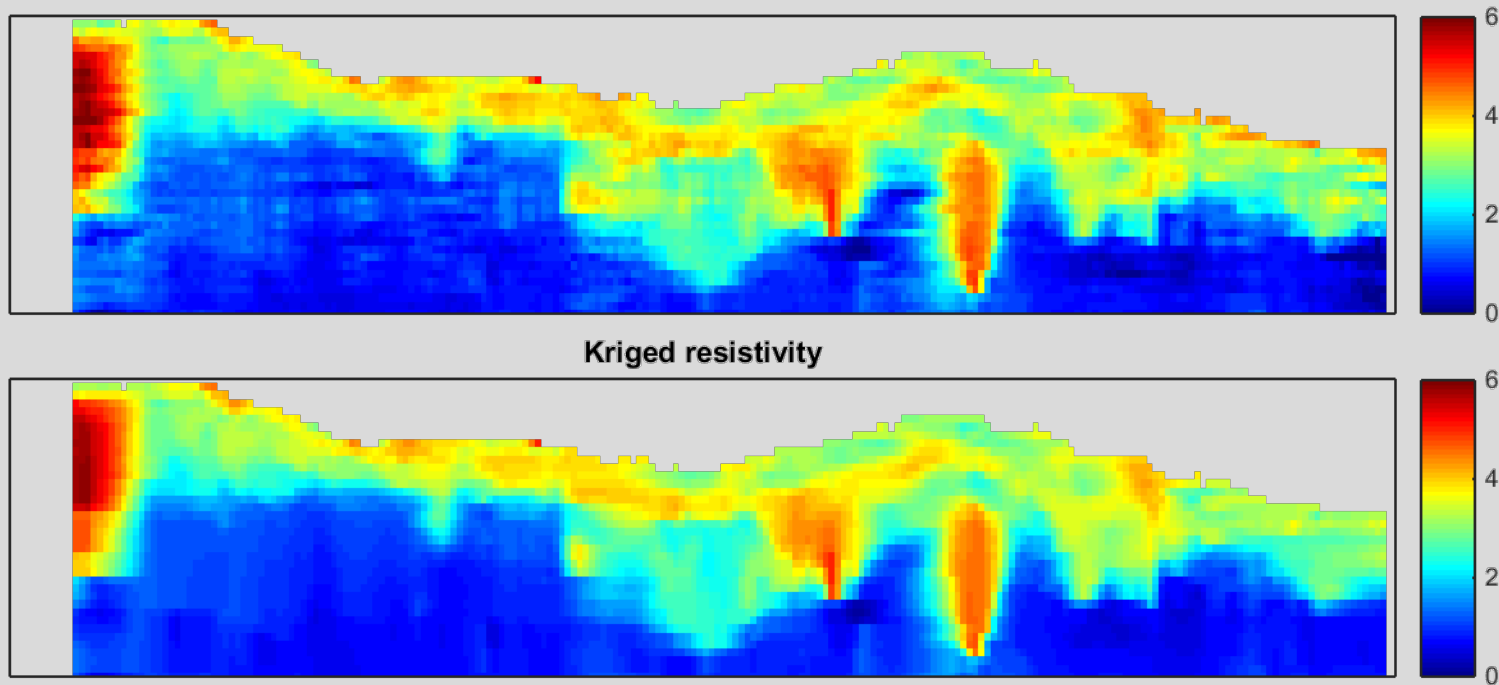
# Usikkerheder i resistivitet



# Usikkerheder i resistivitet

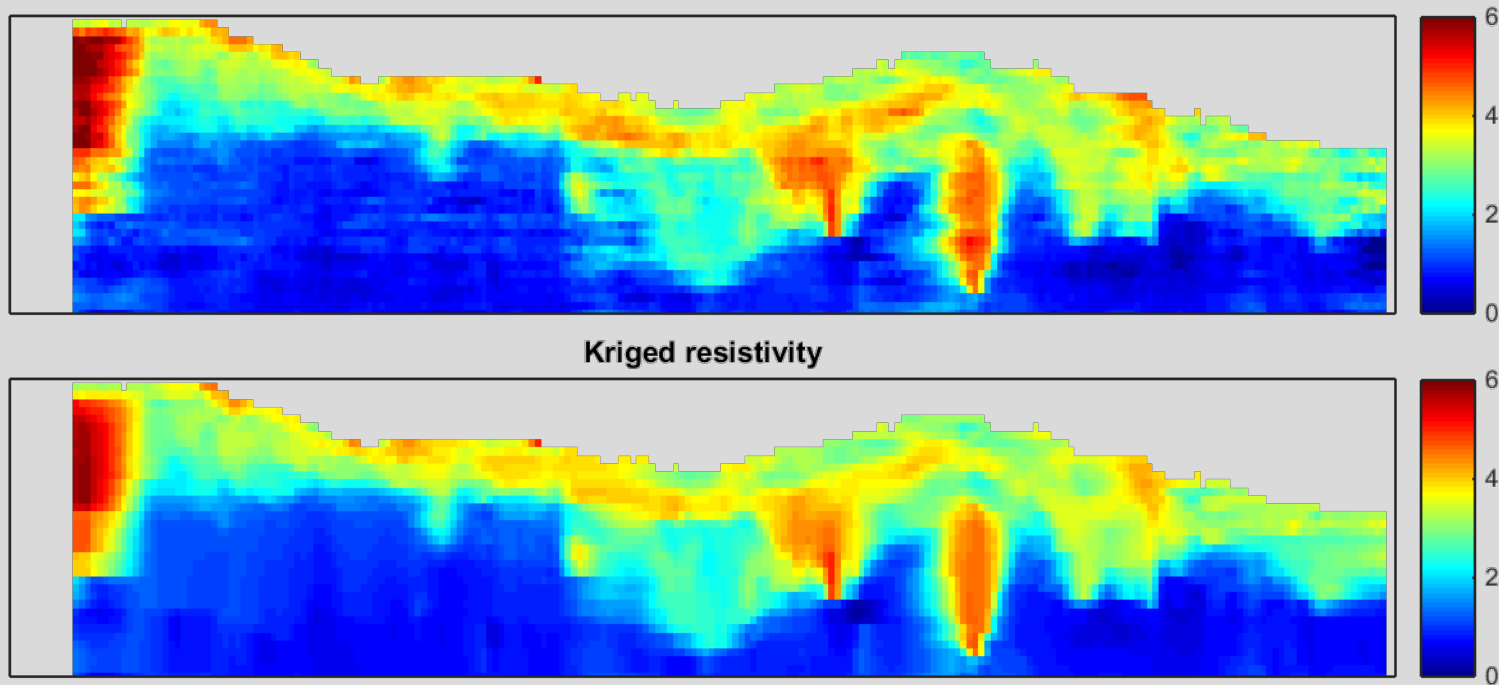


# Usikkerheder i resistivitet

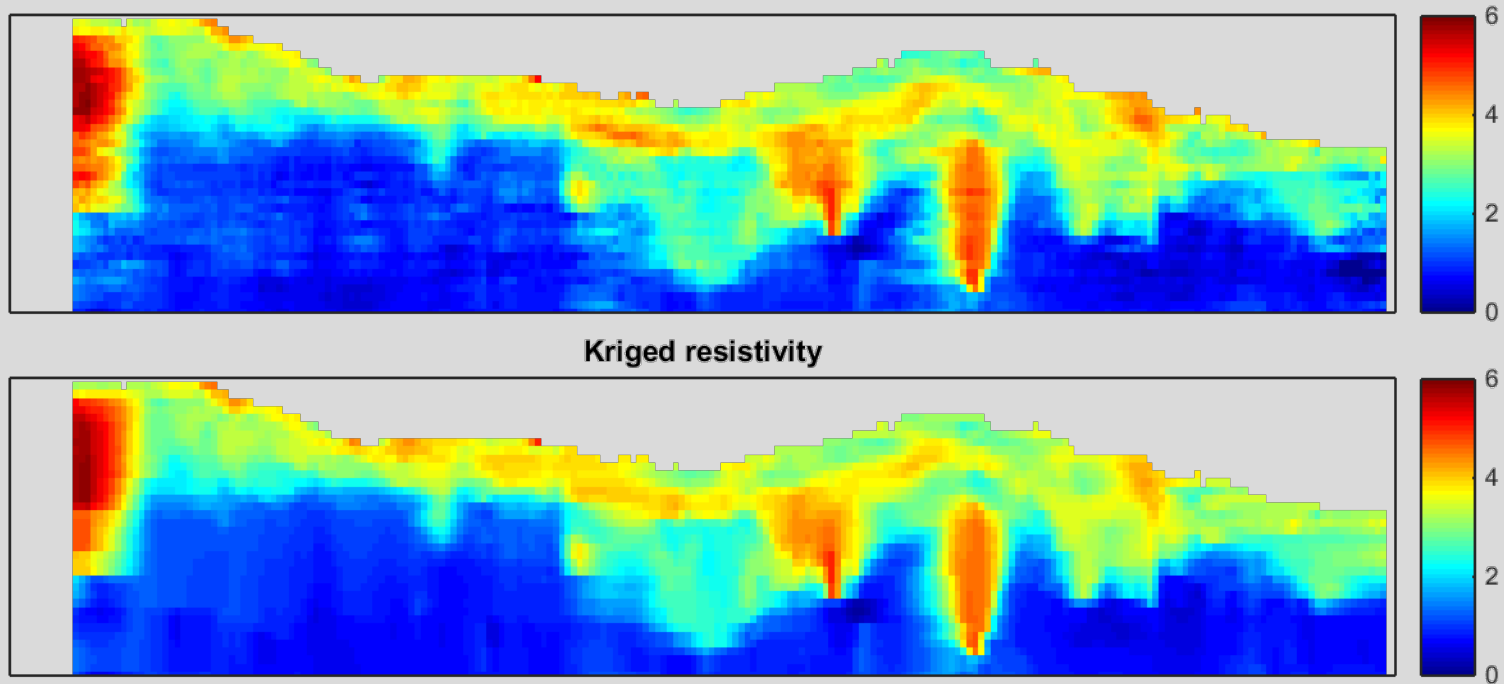




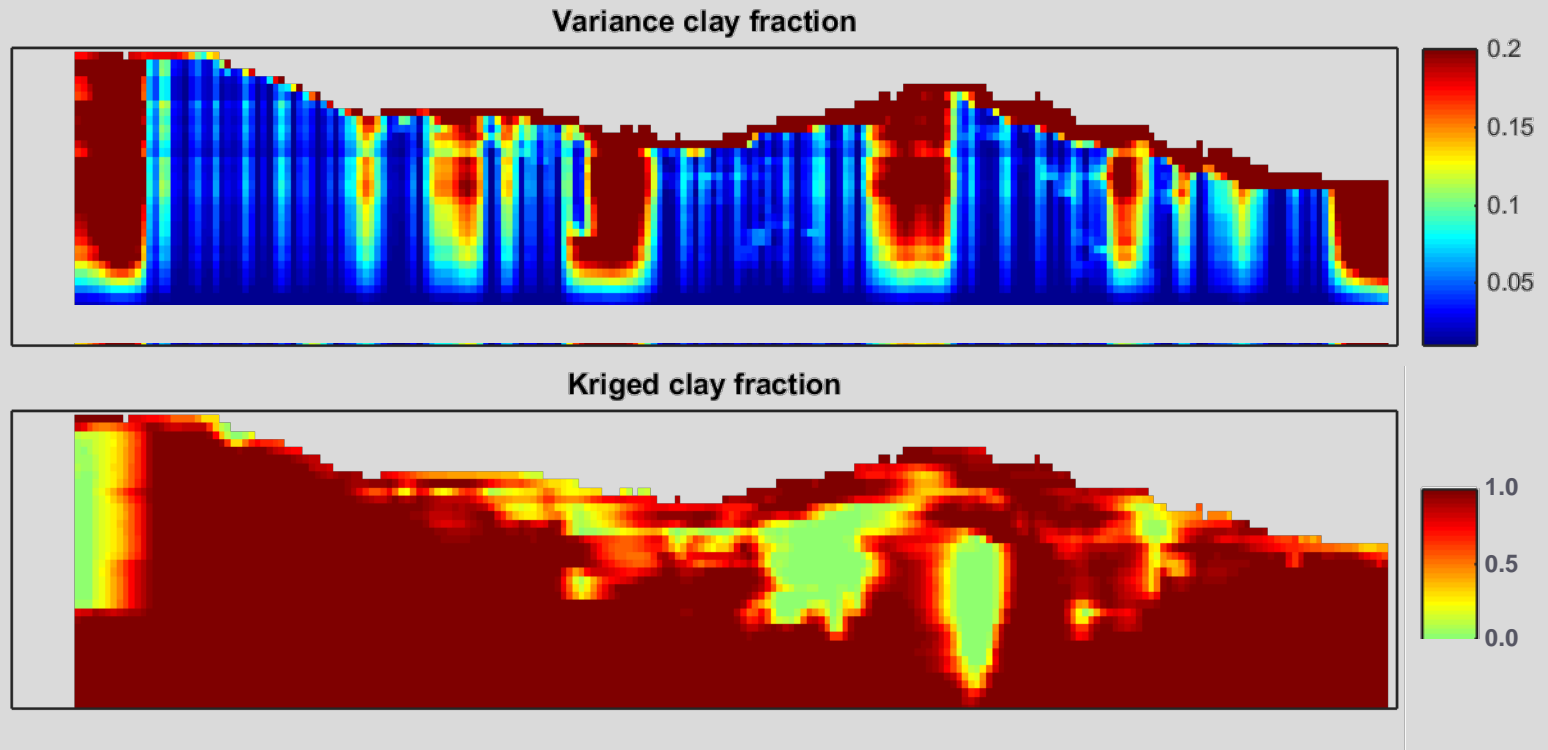
# Usikkerheder i resistivitet



# Usikkerheder i resistivitet

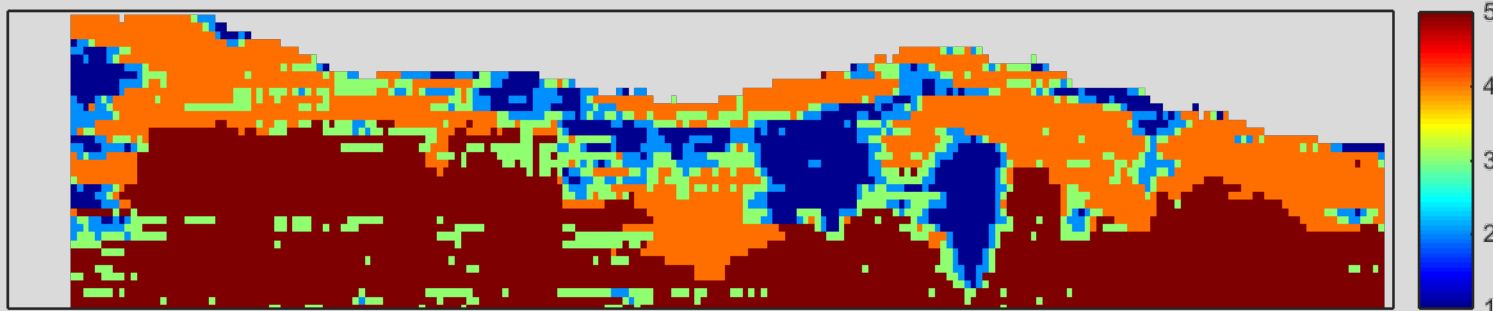


# Usikkerheder i CF

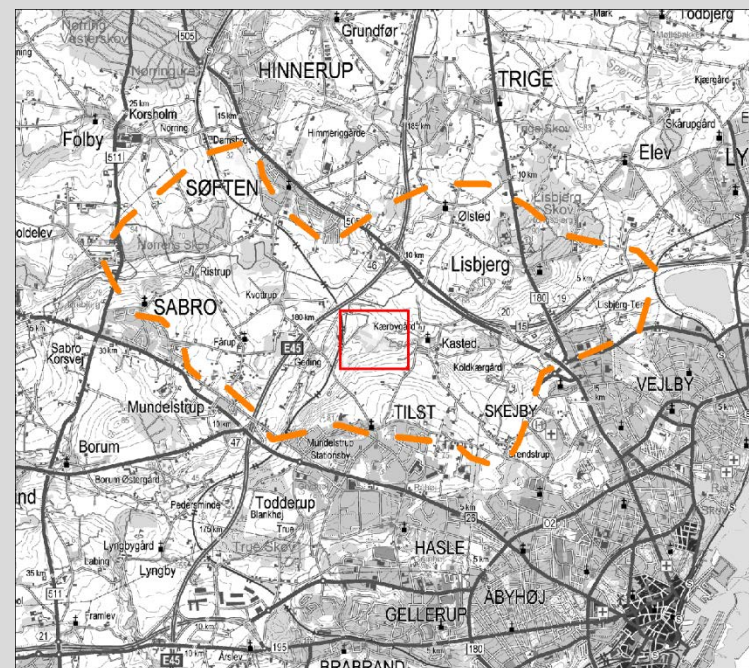
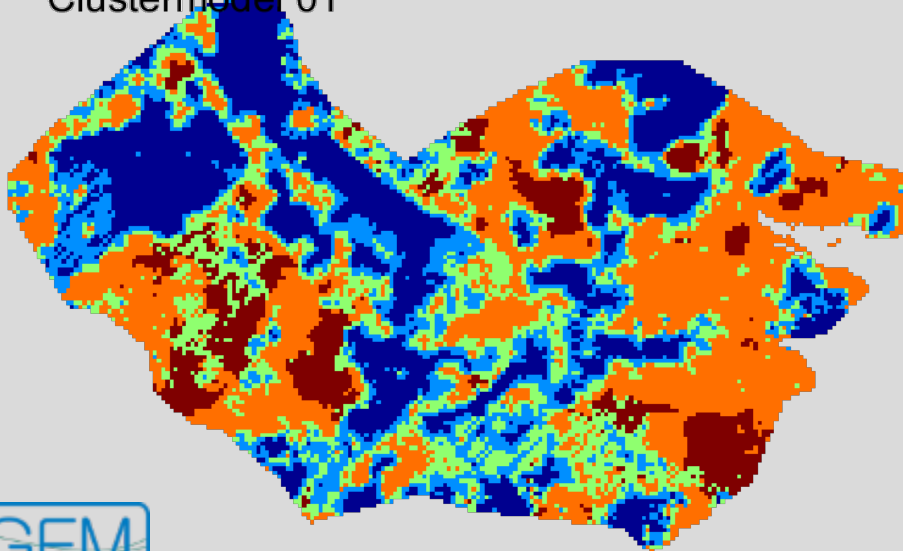


# Usikkerheder i Cluster Modeller

Clustermodel 01

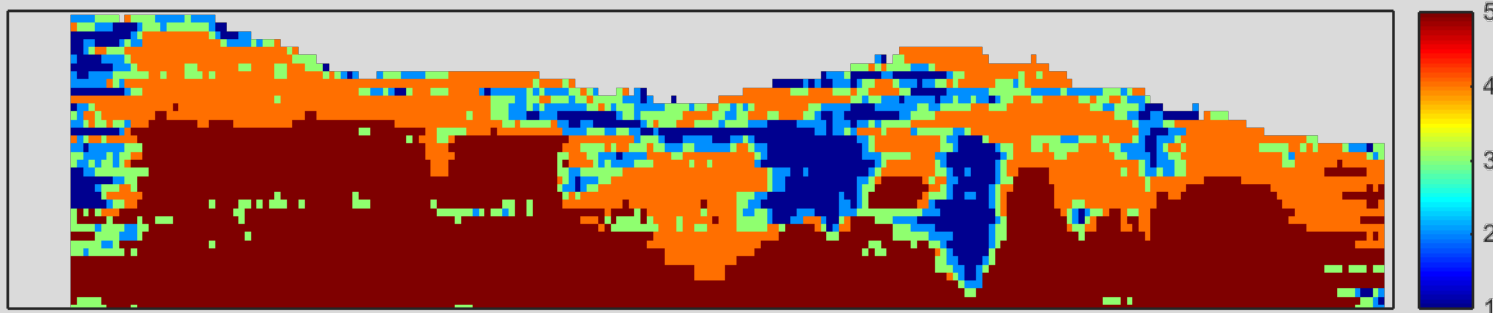


Clustermodel 01

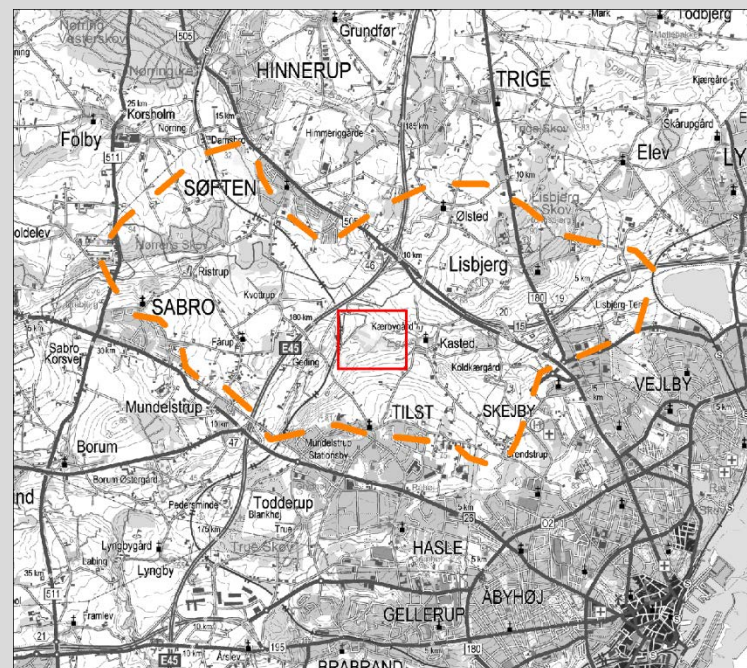
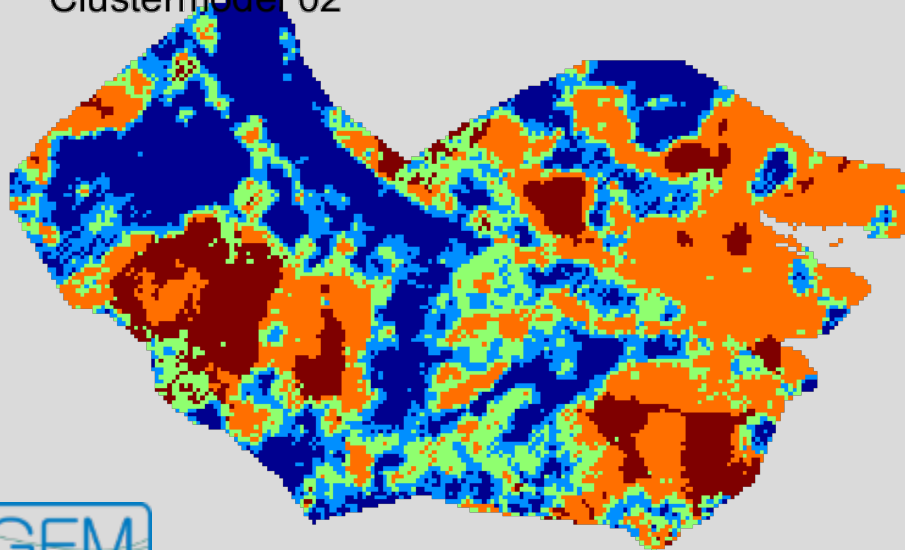


# Usikkerheder i Cluster Modeller

Clustermodel 02



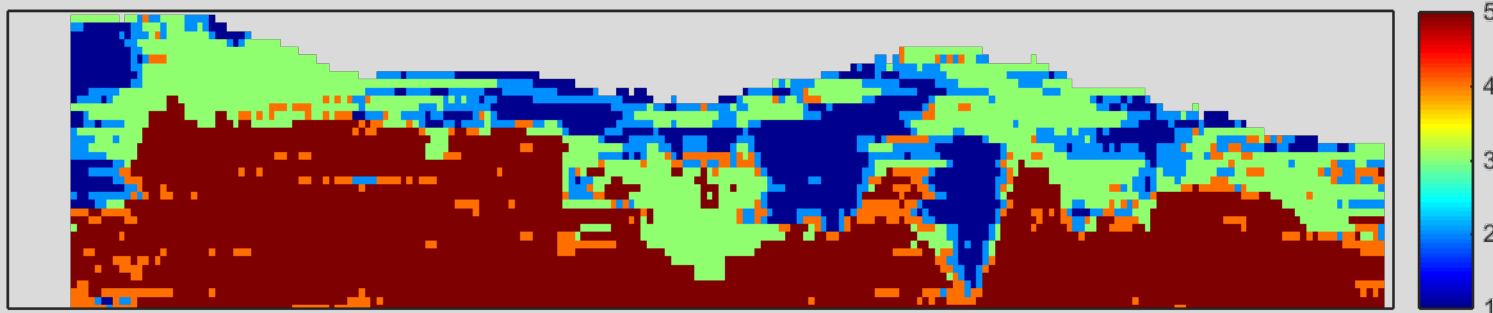
Clustermodel 02



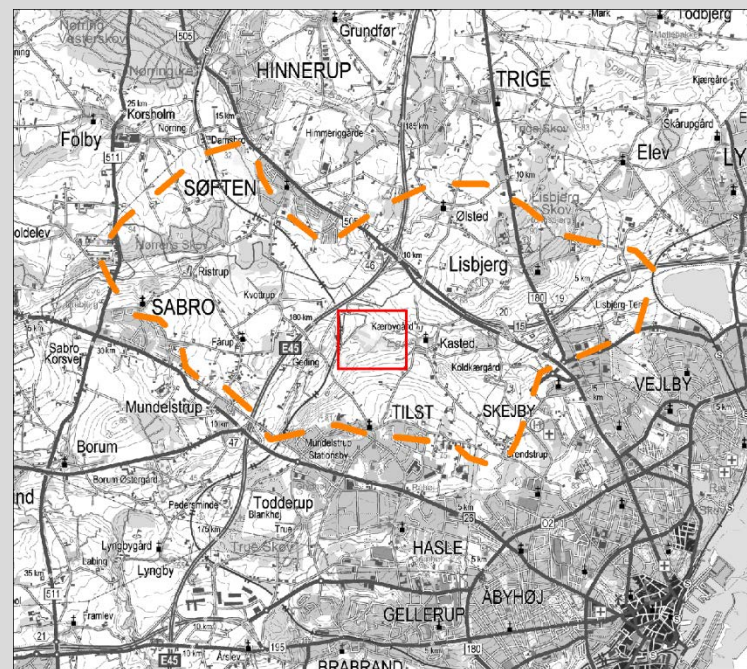
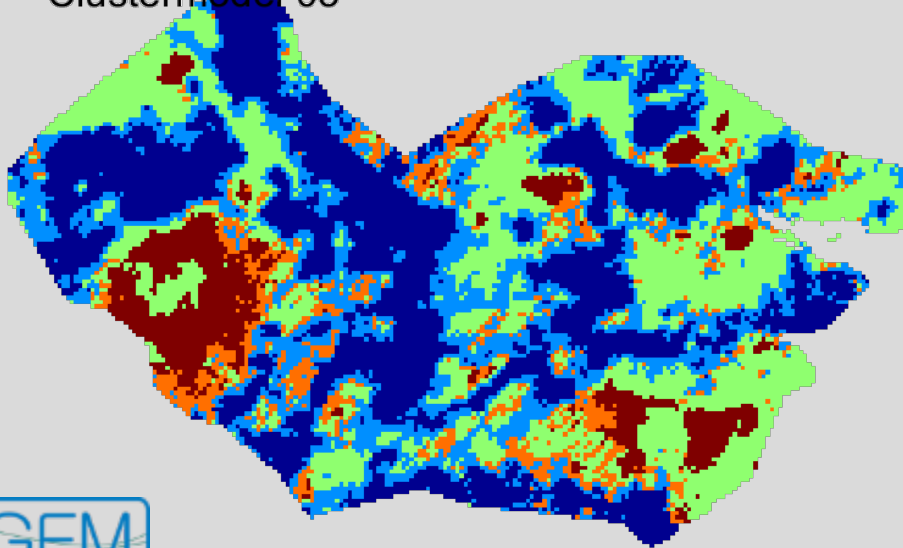


# Usikkerheder i Cluster Modeller

Clustermodel 03

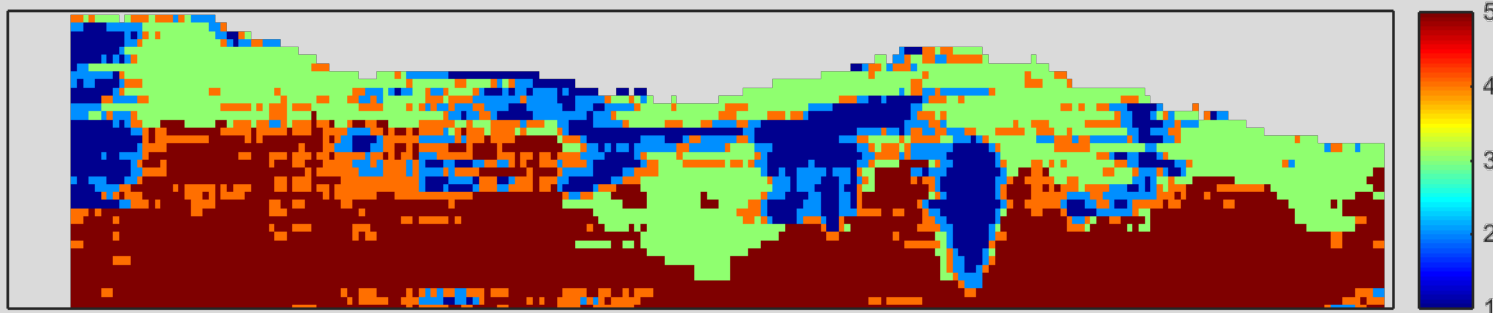


Clustermodel 03

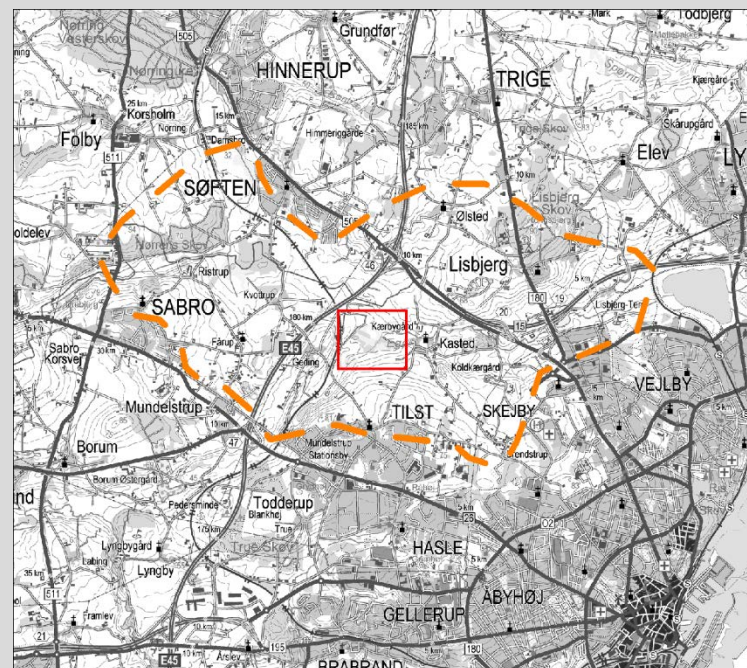
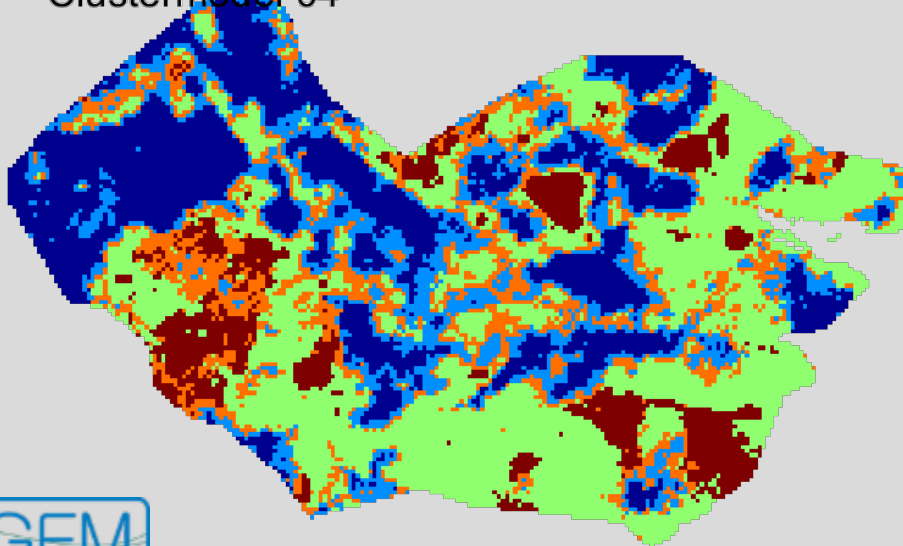


# Usikkerheder i Cluster Modeller

Clustermodel 04

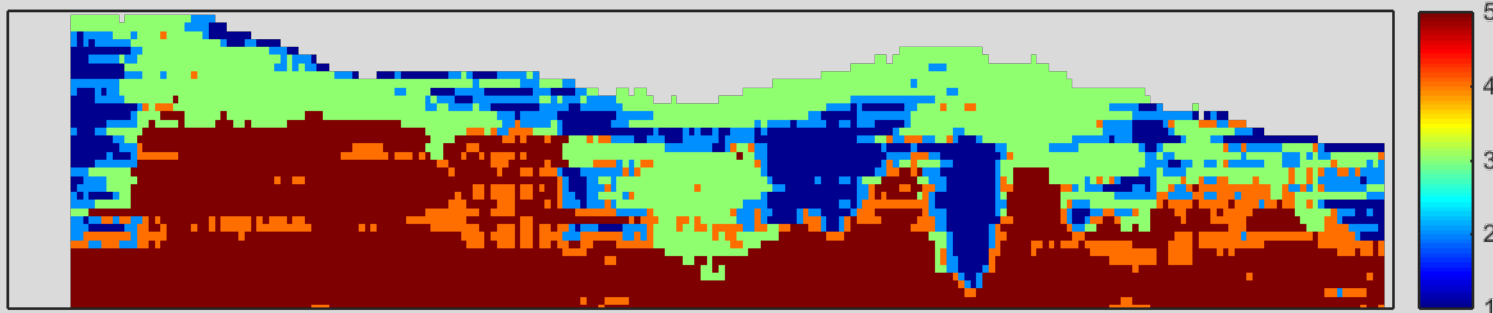


Clustermodel 04

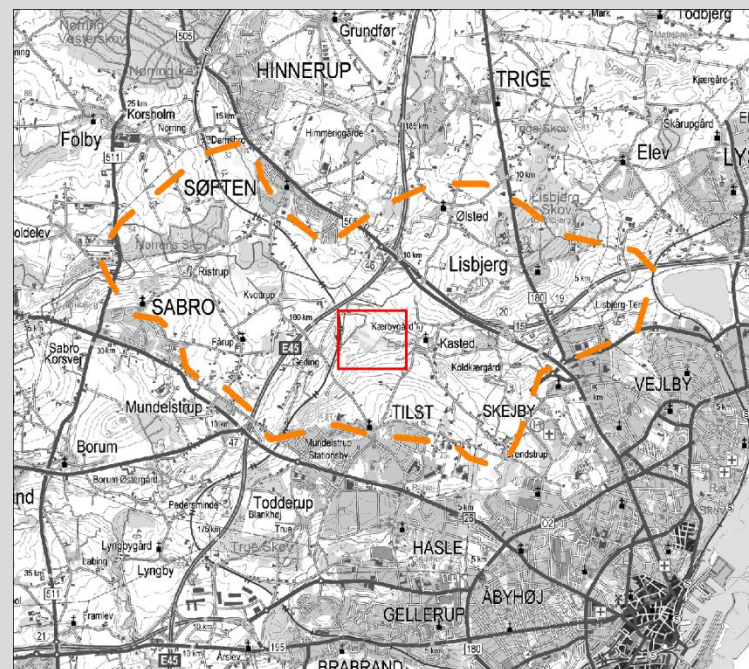
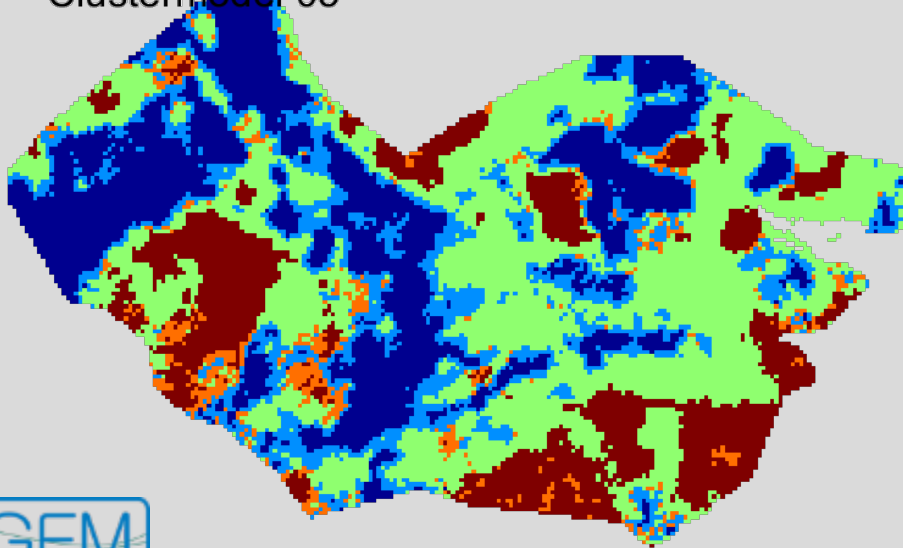


# Usikkerheder i Cluster Modeller

Clustermodel 05



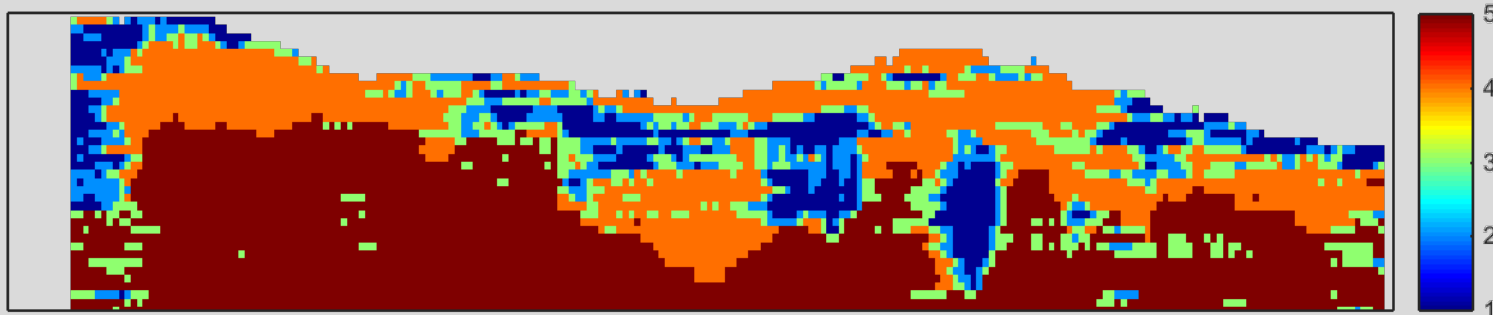
Clustermodel 05



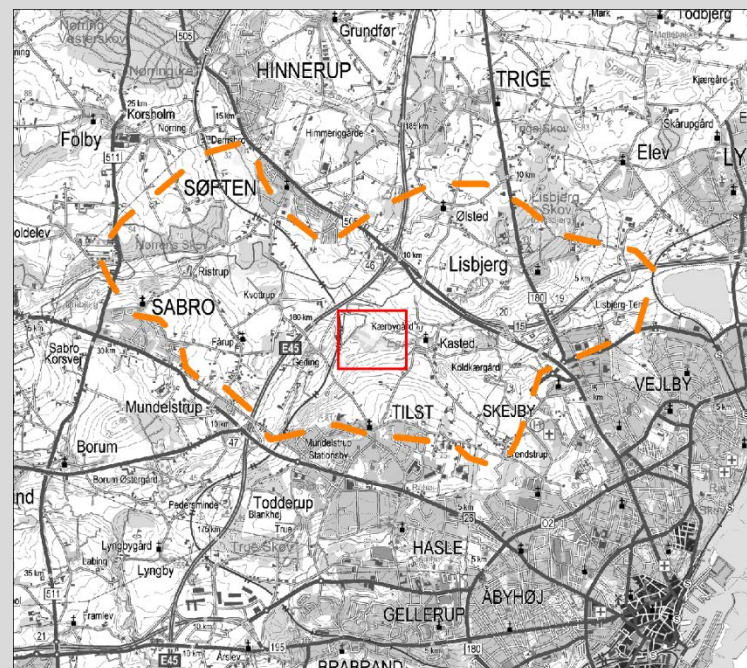
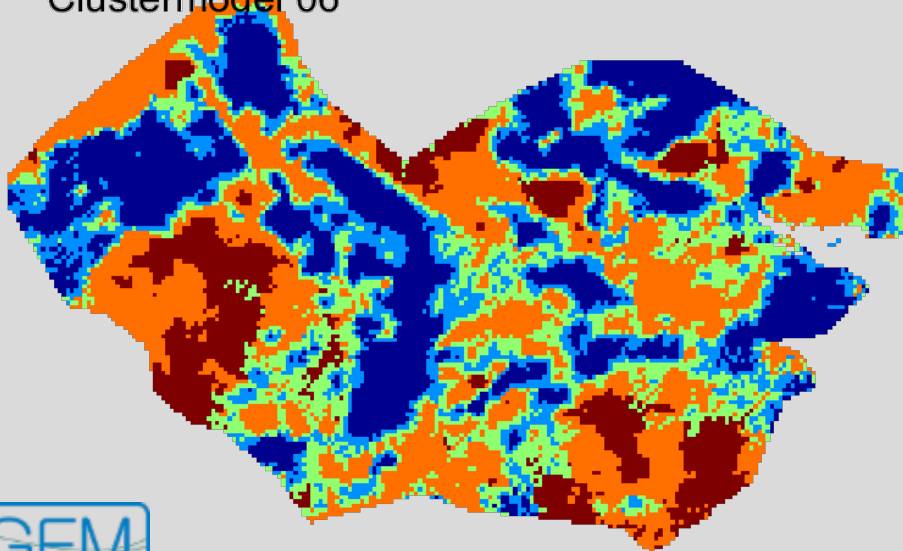


# Usikkerheder i Cluster Modeller

Clustermodel 06

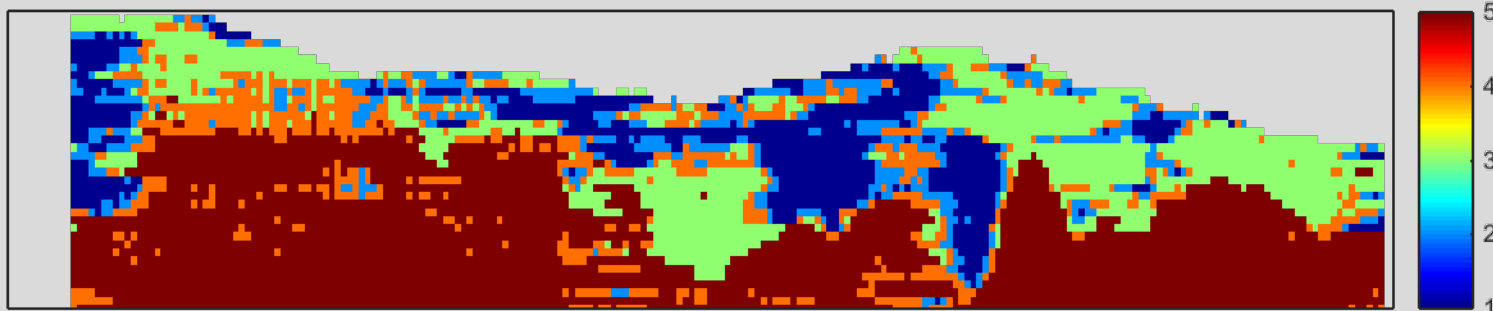


Clustermodel 06

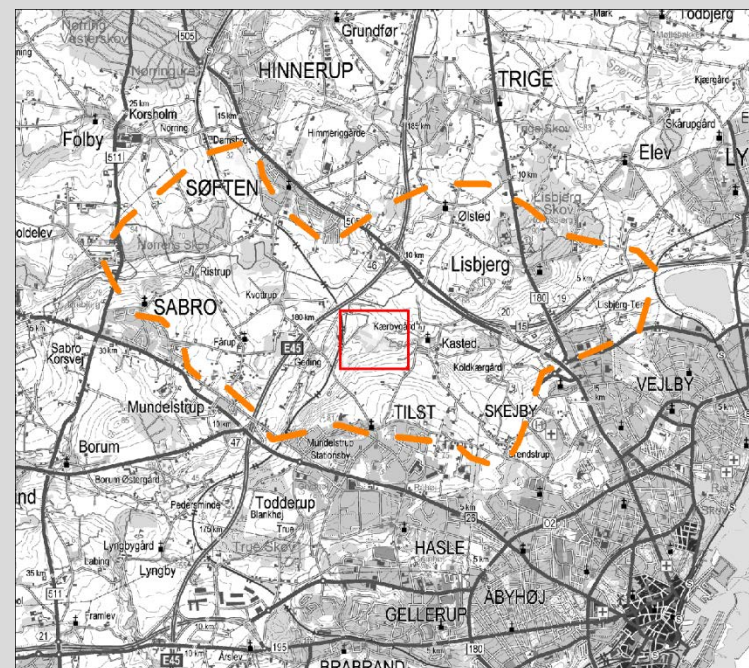
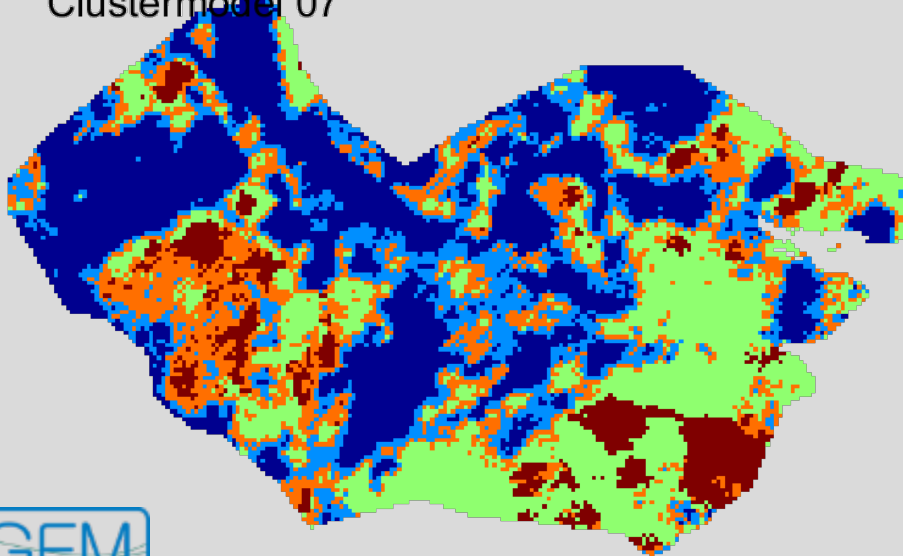


# Usikkerheder i Cluster Modeller

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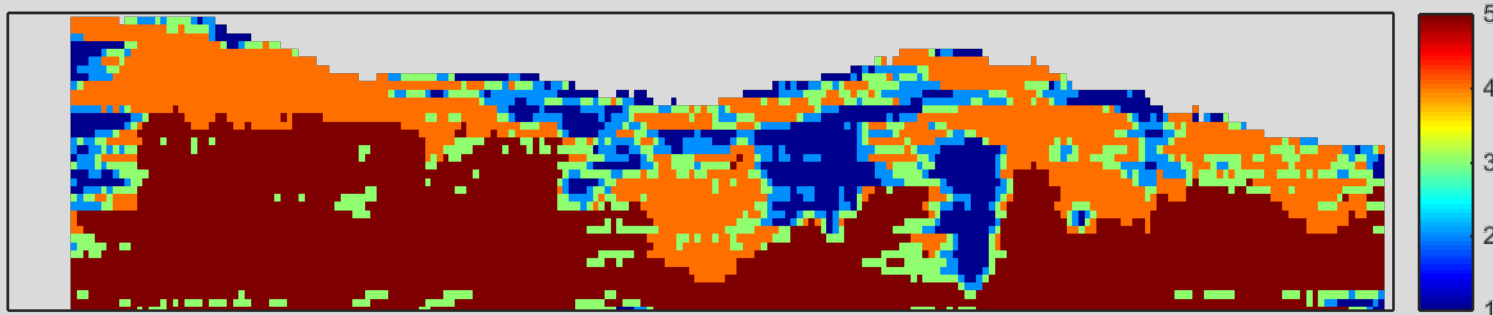


Clustermodel 07

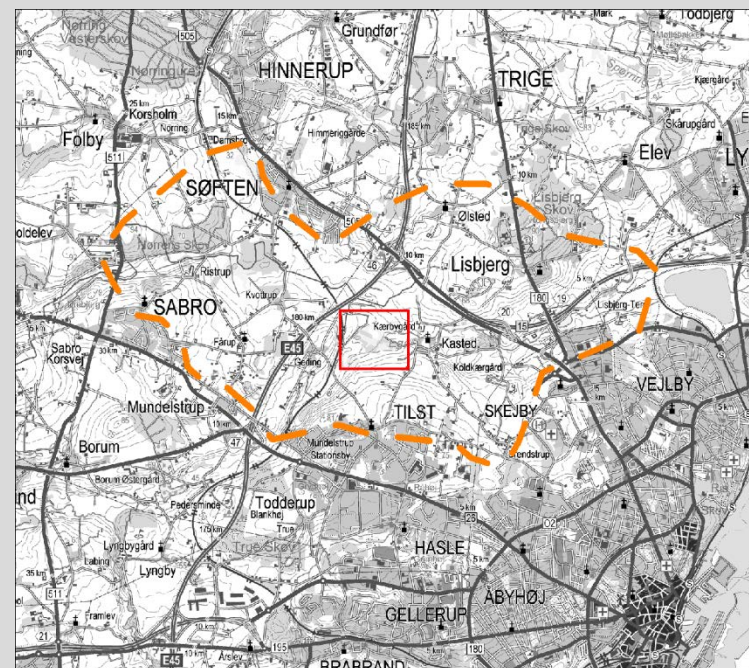
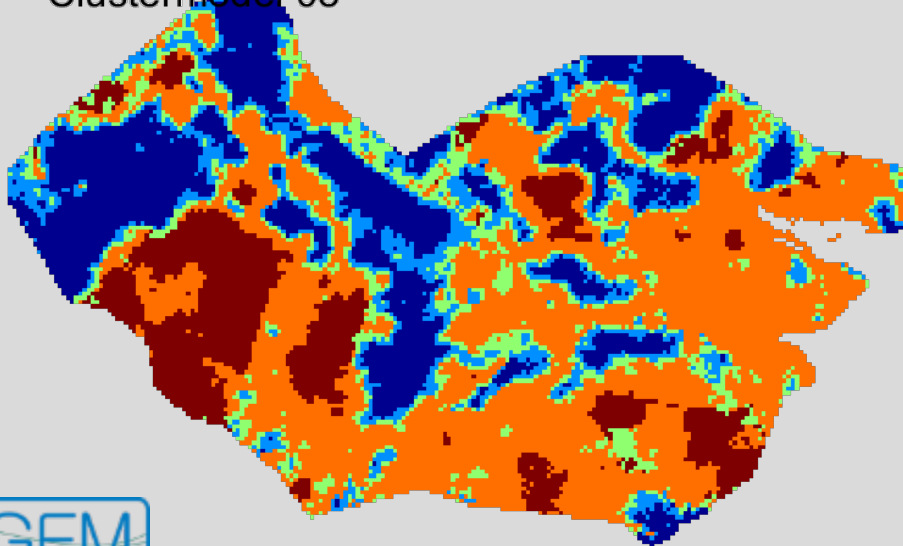


# Usikkerheder i Cluster Modeller

Clustermodel 08

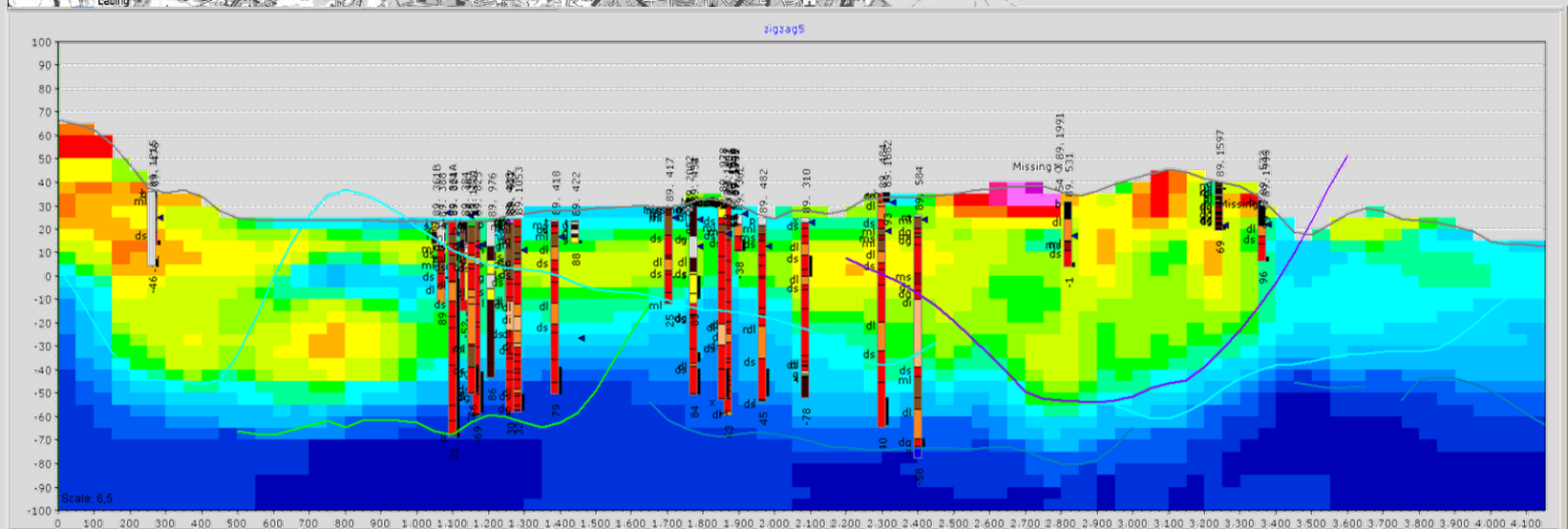
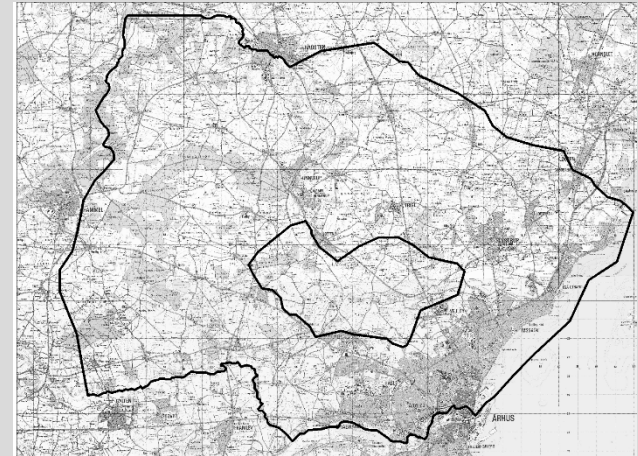
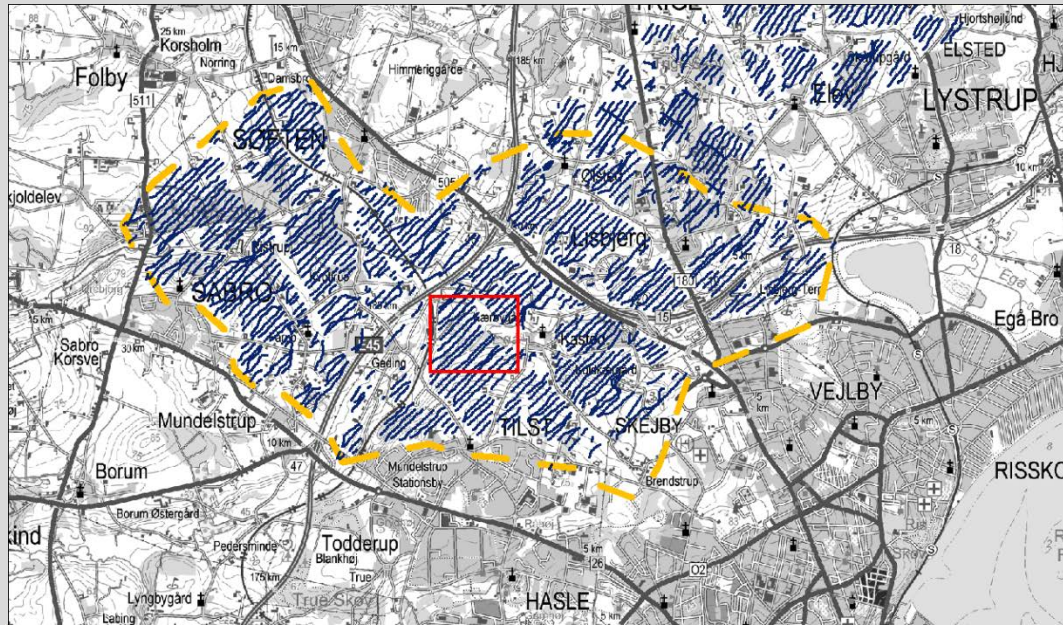


Clustermodel 08

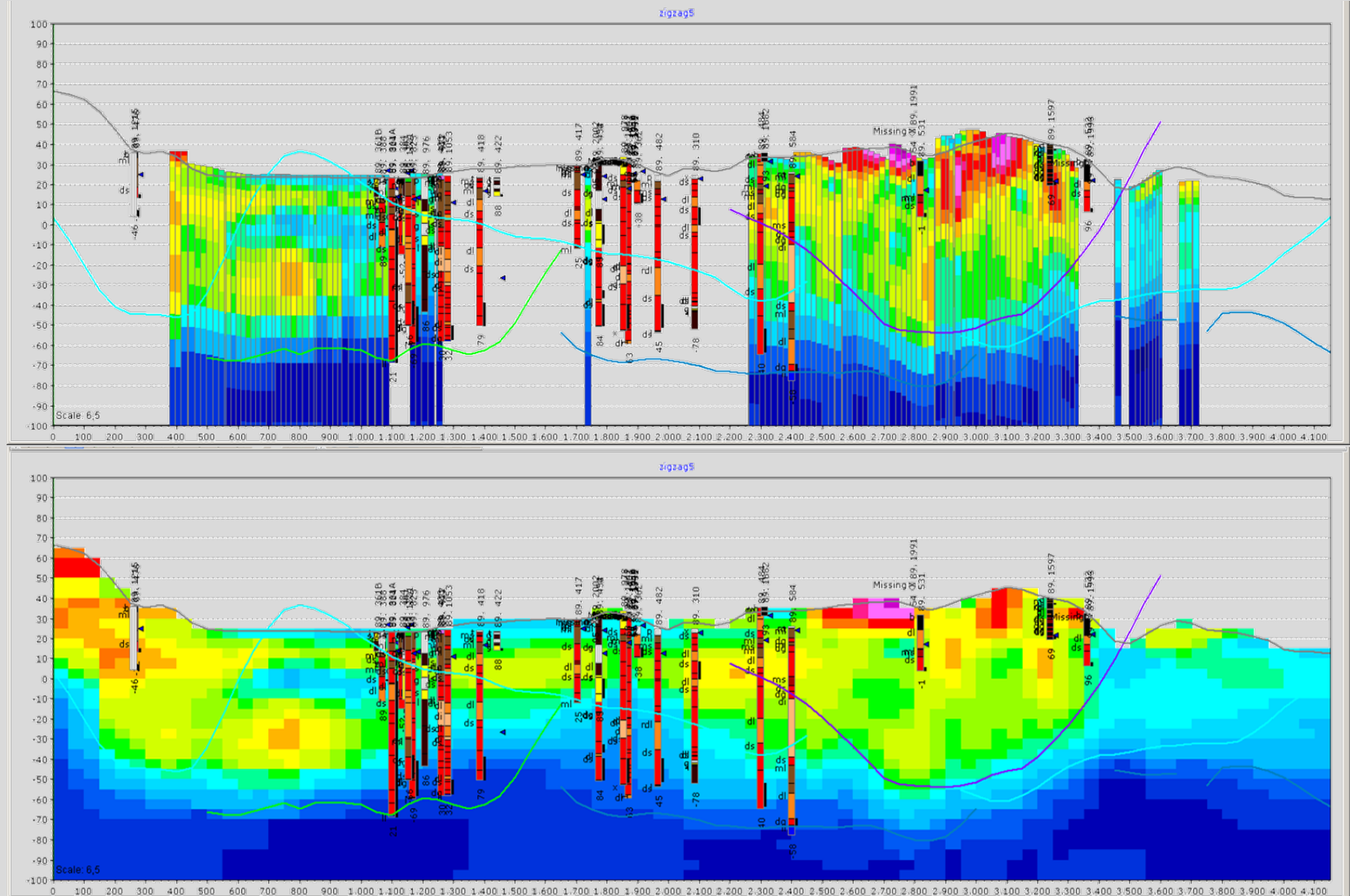




# Område og reference geologisk model

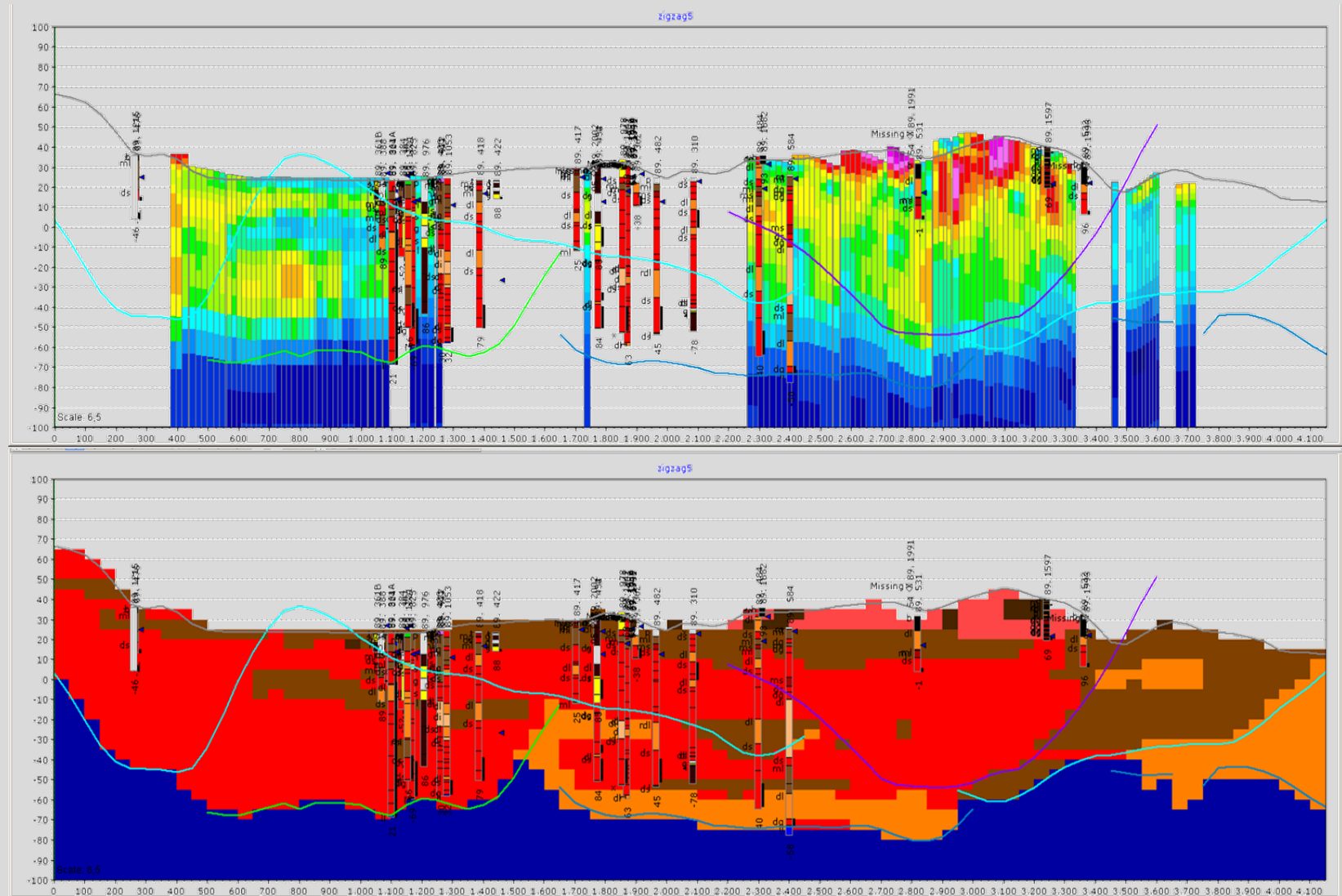


# Reference geologisk model



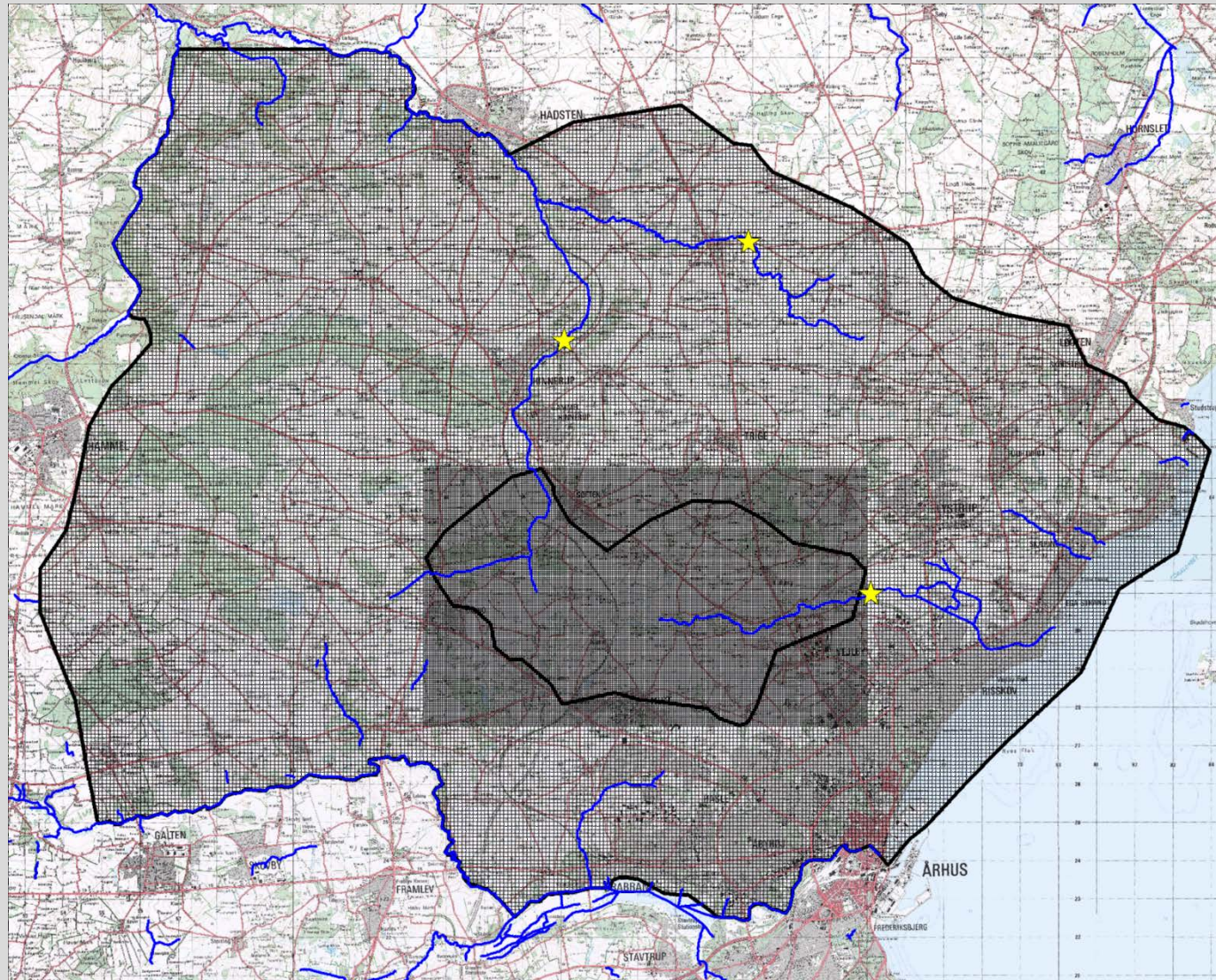


# Reference geologisk model



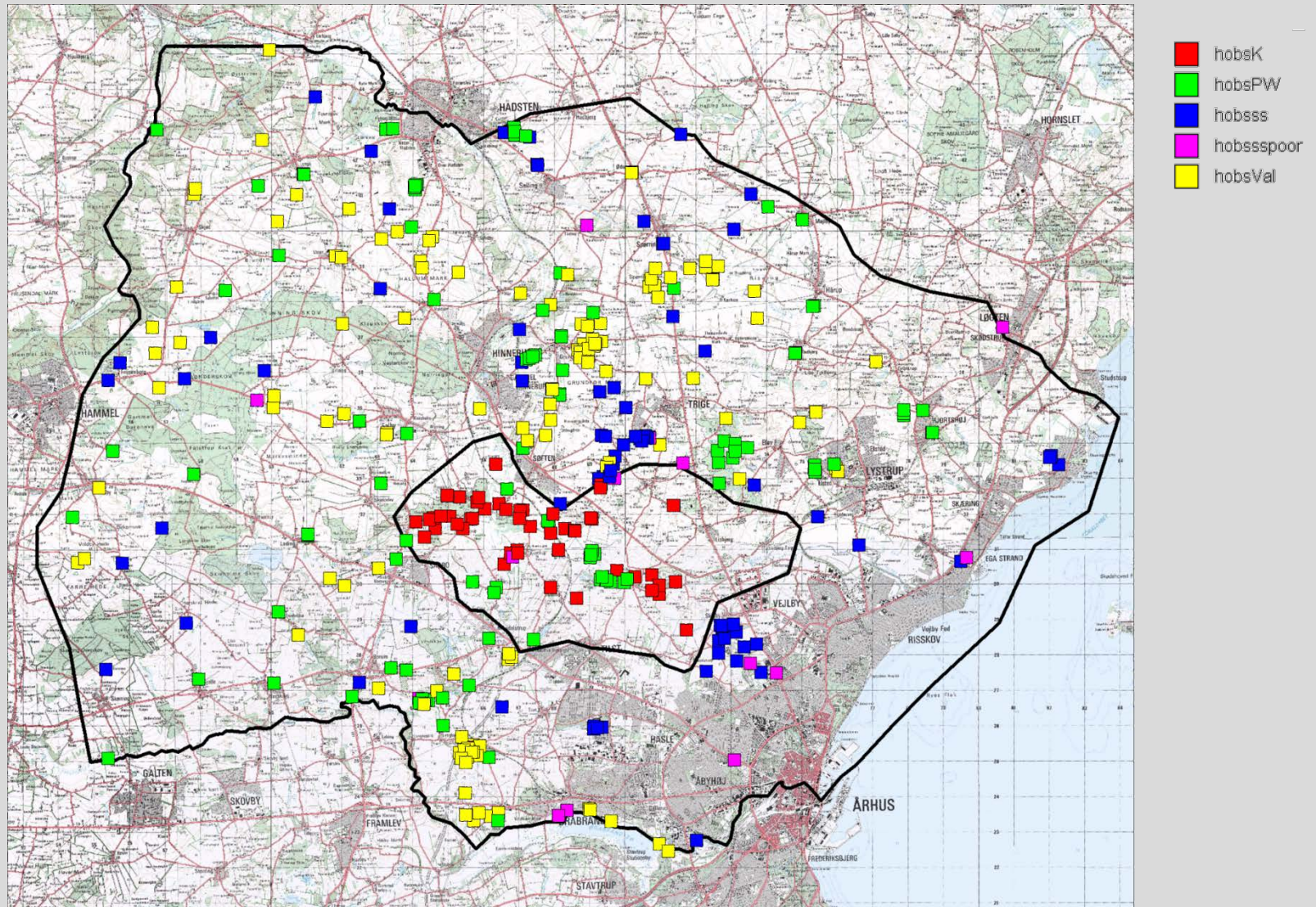


# Model og hydrologiske data

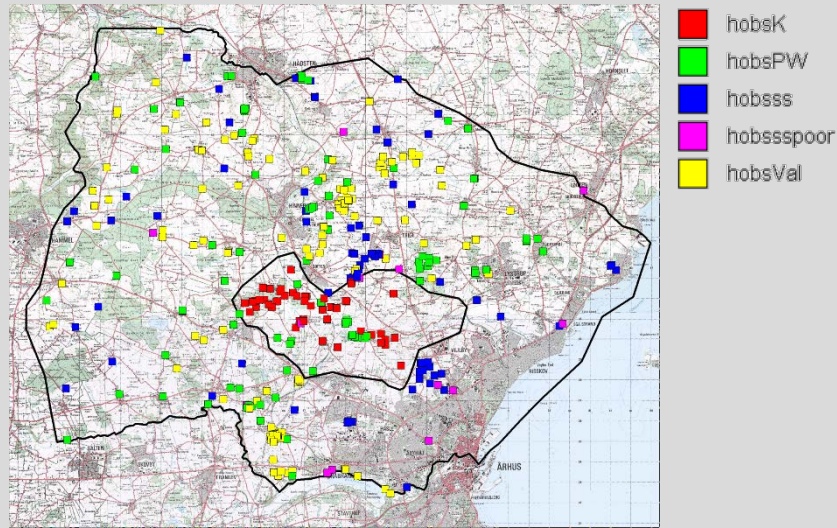




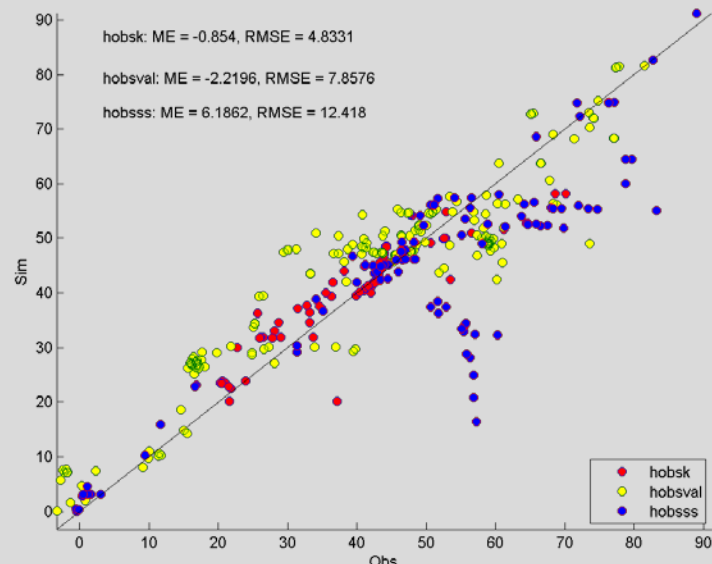
# Model og hydrologiske data



# Model og hydrologiske data

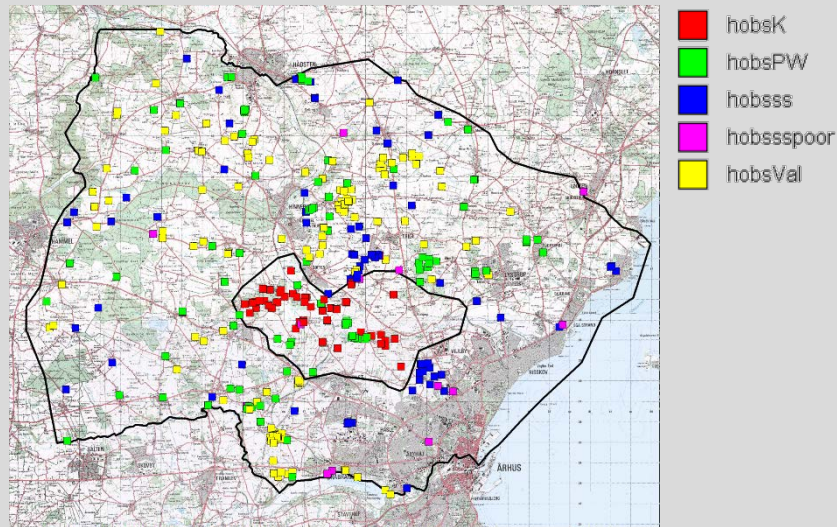


## Reference model

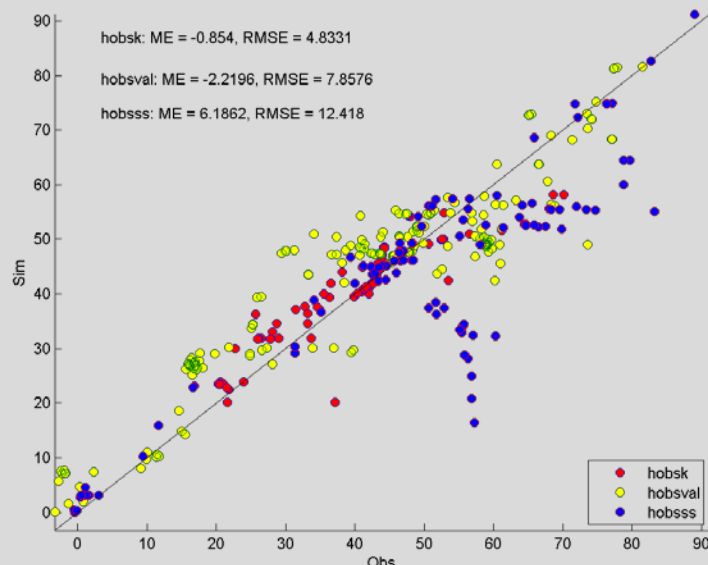




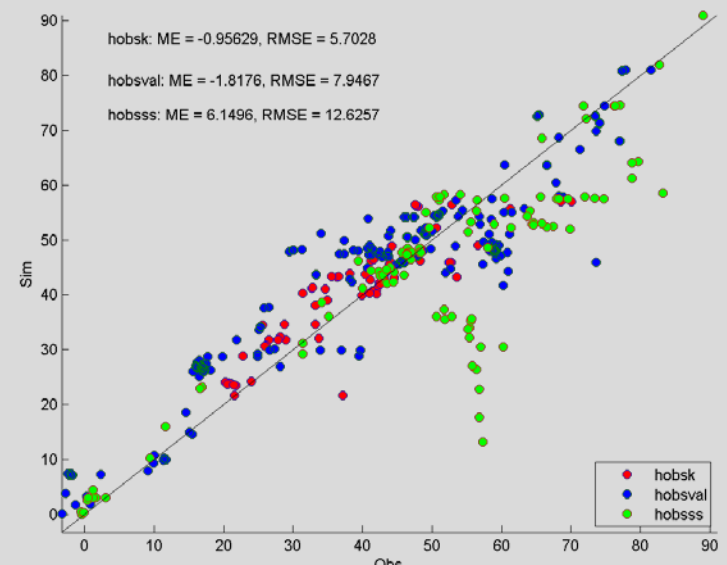
# Model og hydrologiske data



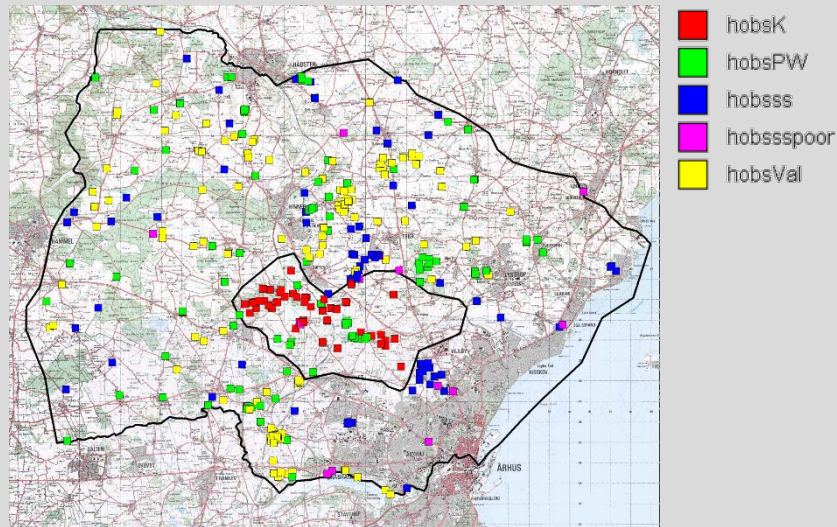
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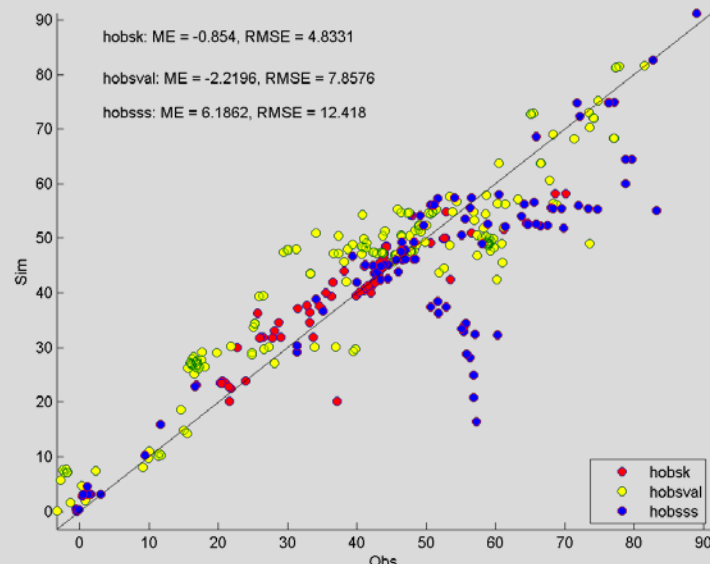
## Cluster model 1



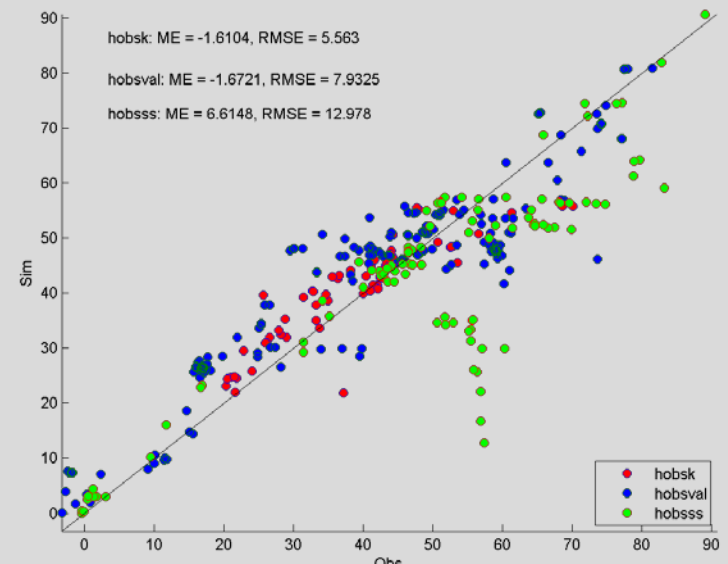
# Model og hydrologiske data



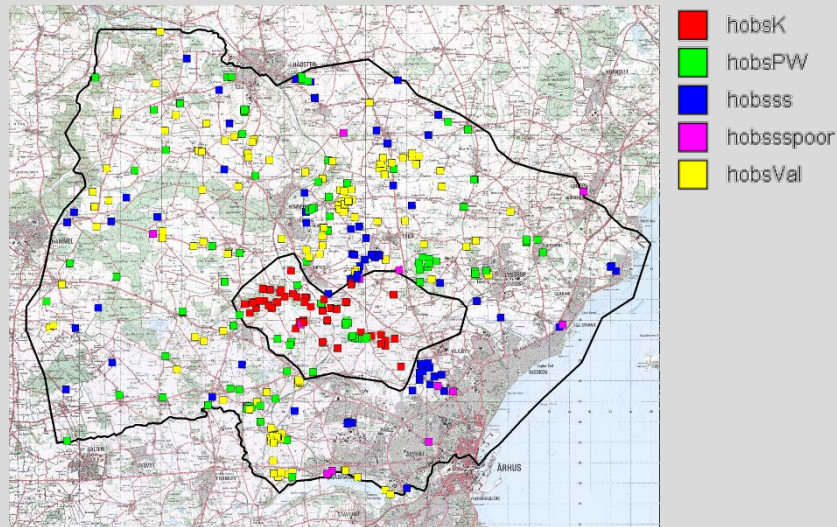
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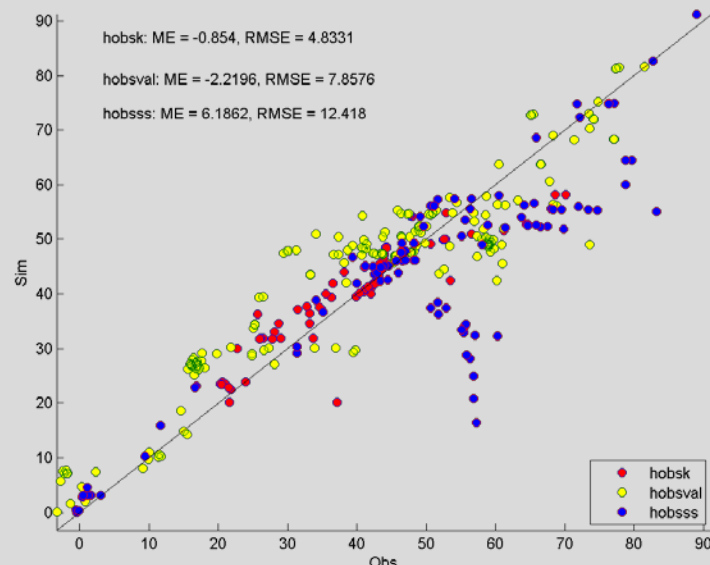
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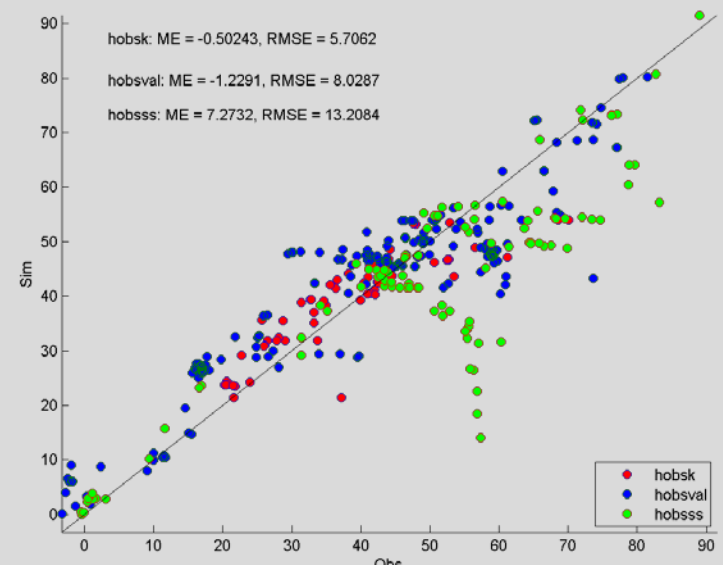
# Model og hydrologiske data



## Reference model

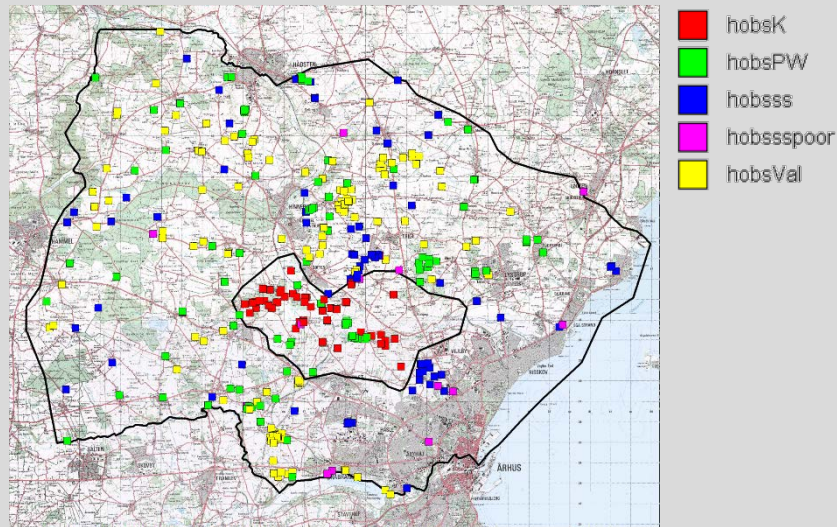


## Cluster model 3

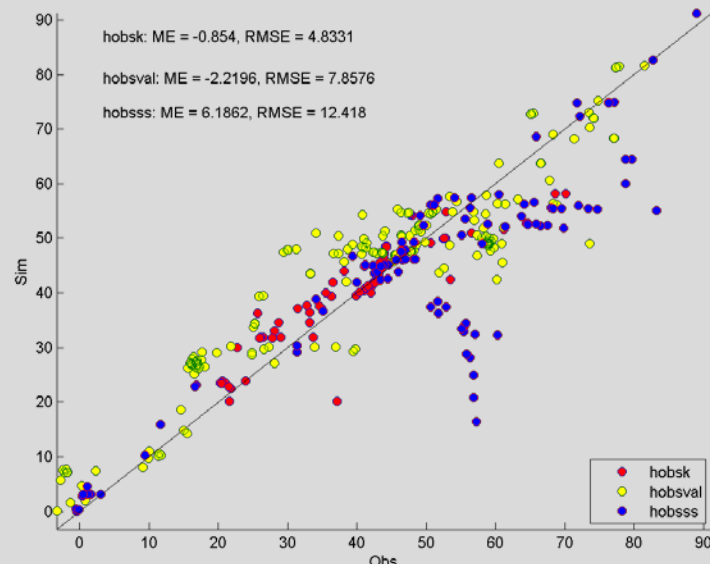




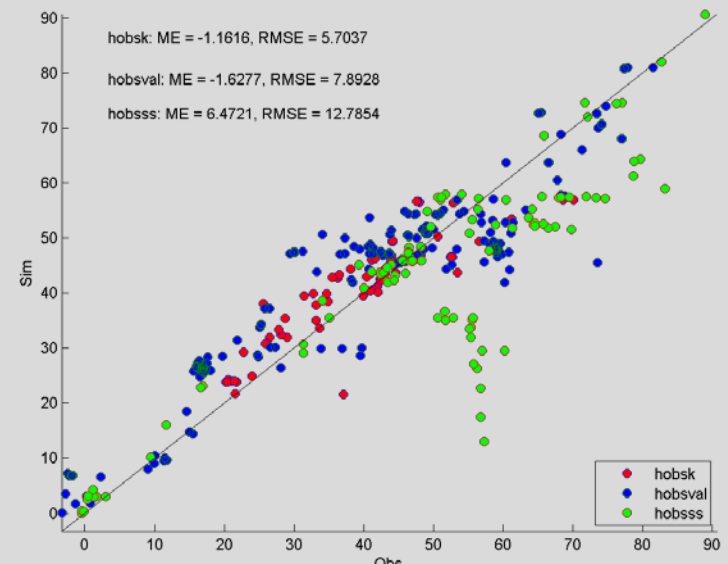
# Model og hydrologiske data



## Reference model

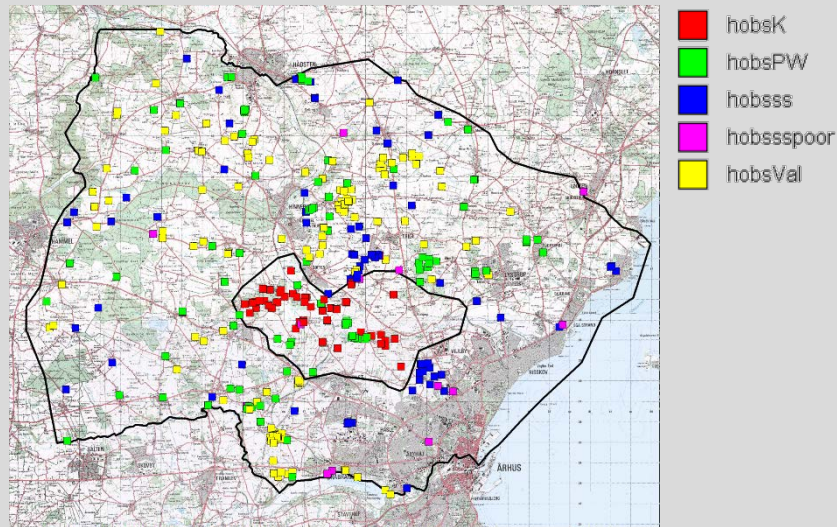


## Cluster model 4

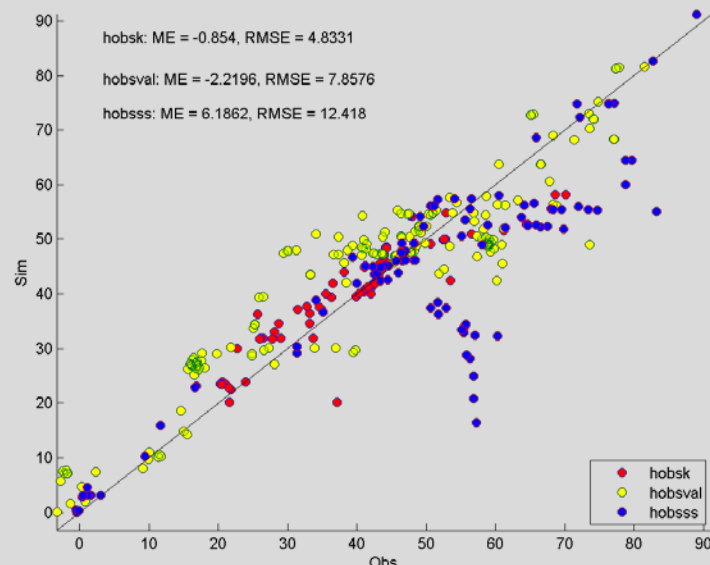




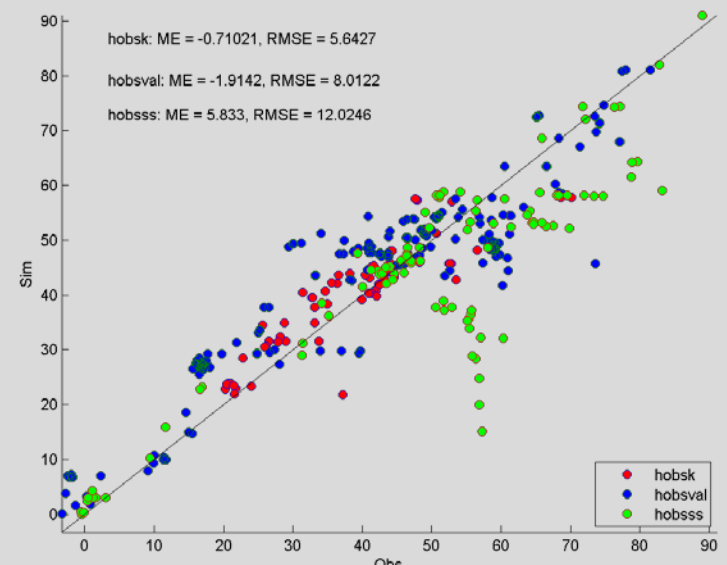
# Model og hydrologiske data



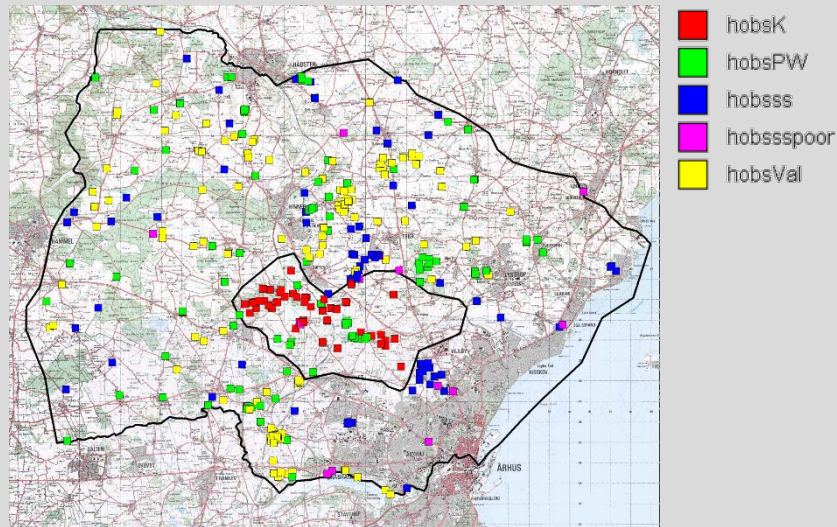
## Reference model



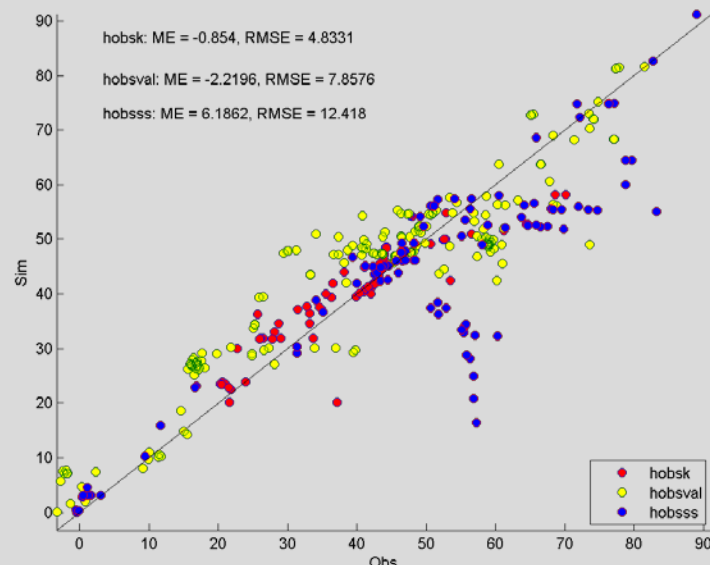
## Cluster model 5



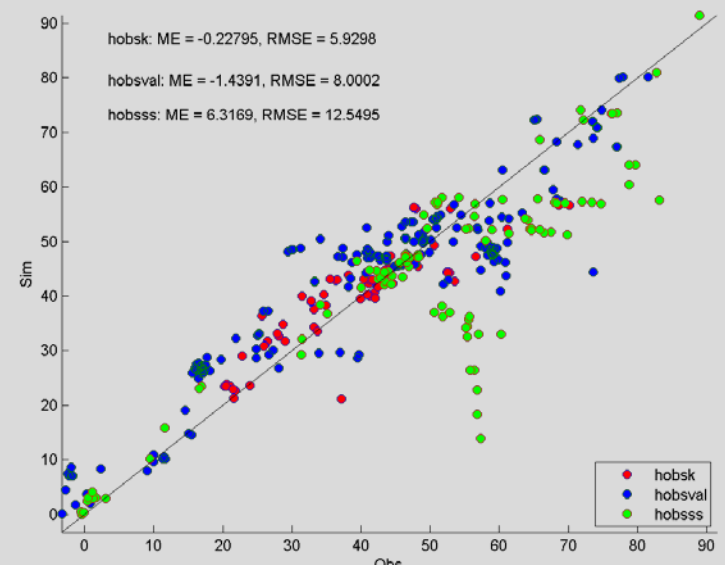
# Model og hydrologiske data



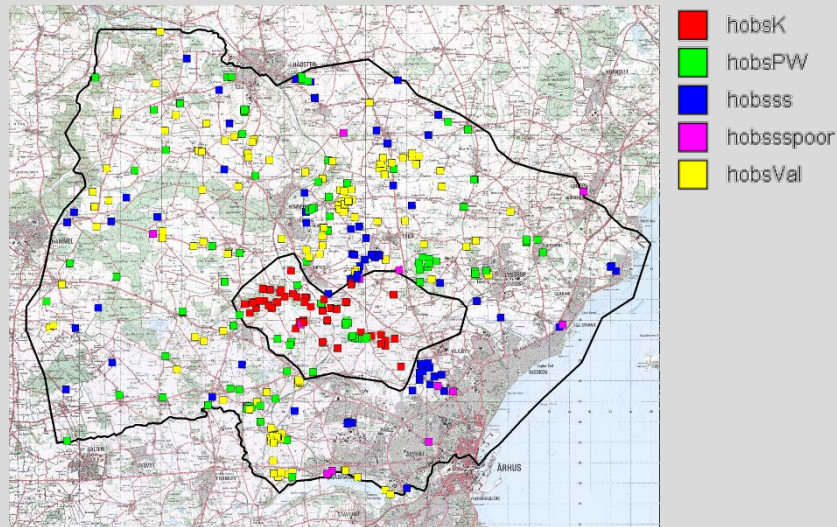
## Reference model



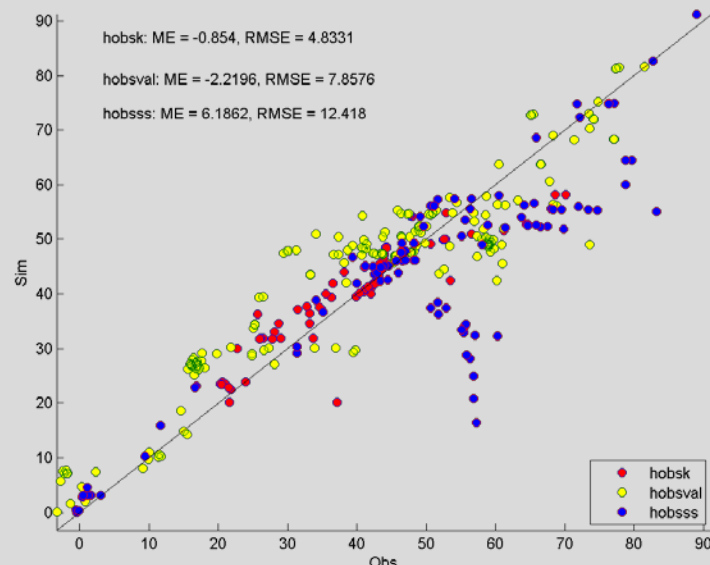
## Cluster model 6



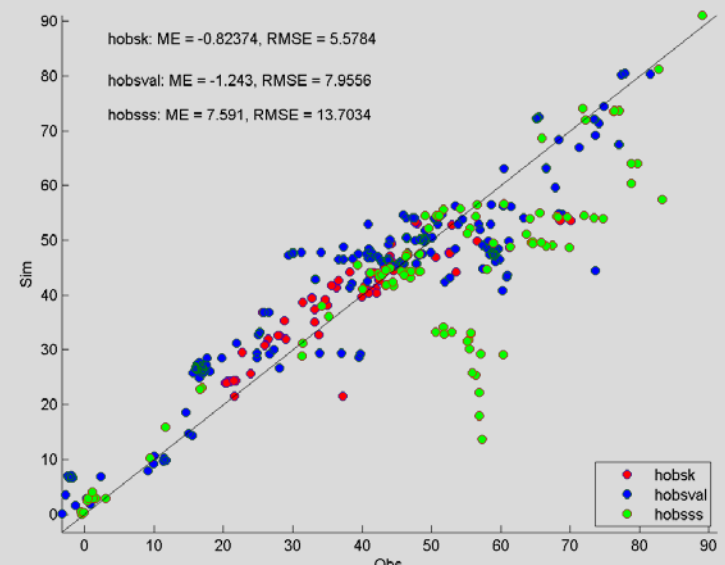
# Model og hydrologiske data



## Reference model

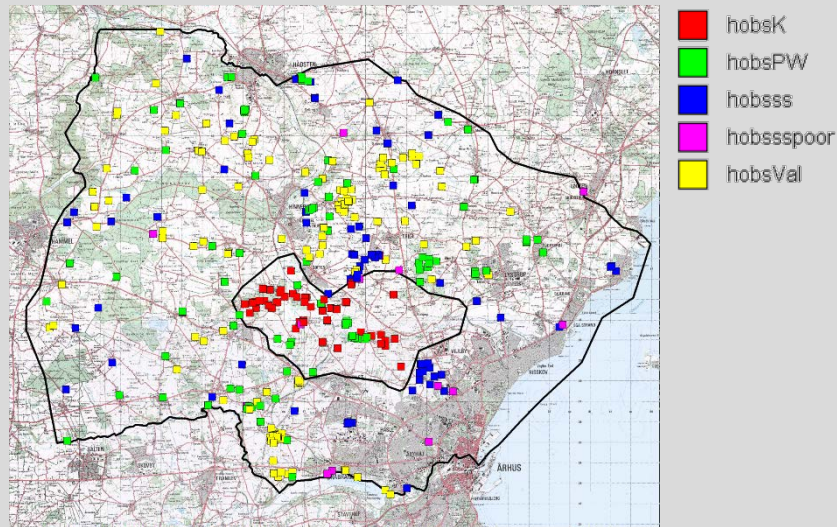


## Cluster model 7

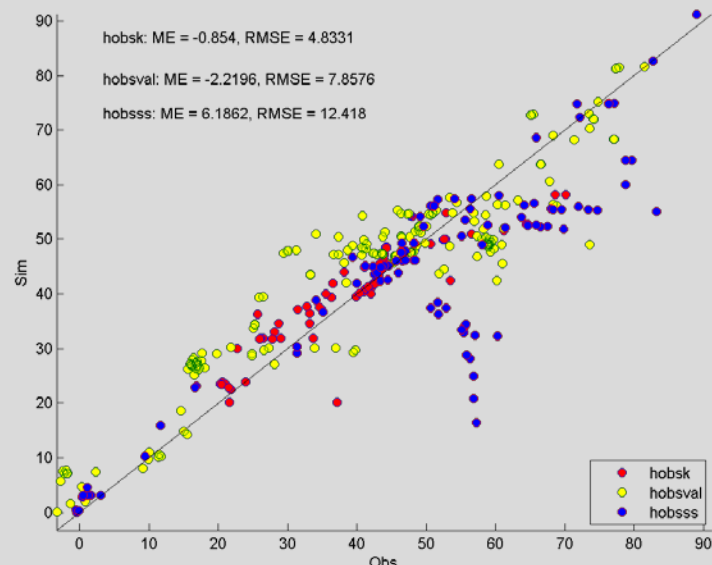




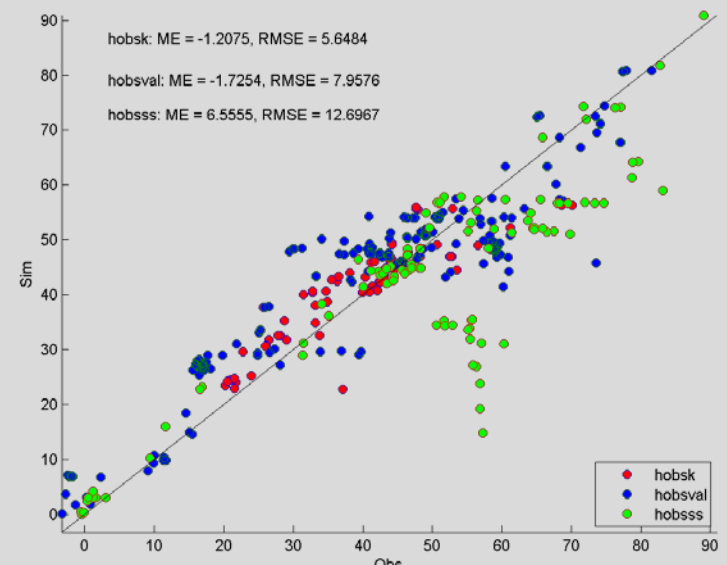
# Model og hydrologiske data



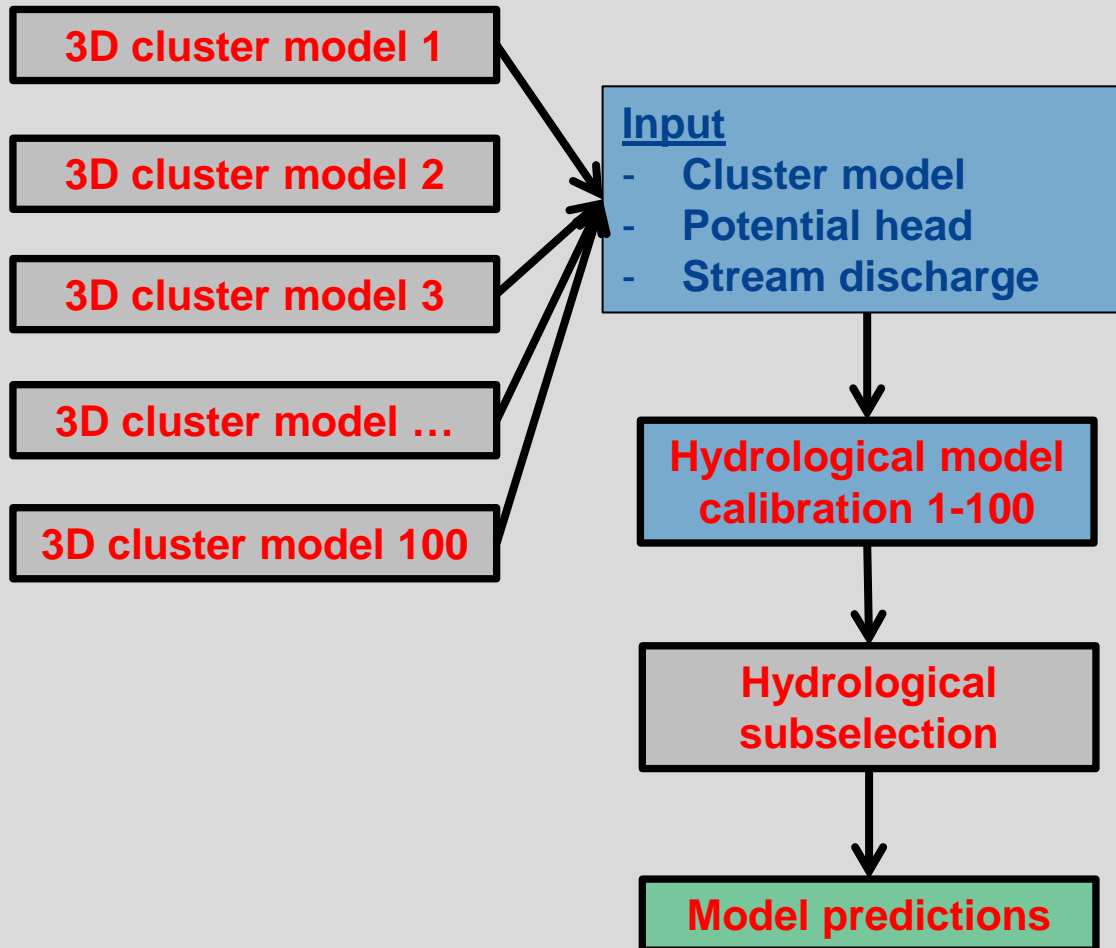
## Reference model



## Cluster model 8



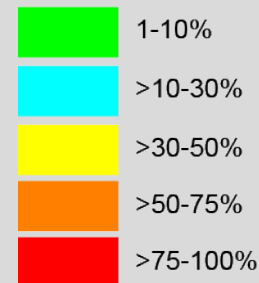
# Model Uncertainty



# Oplandsusikkerhed

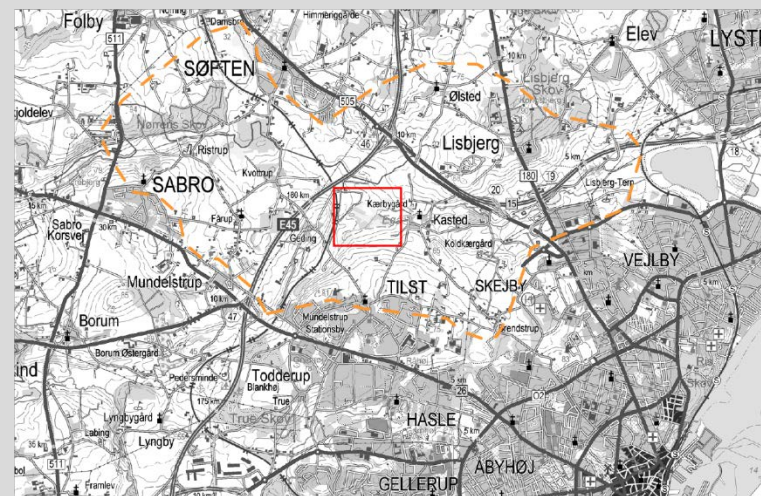
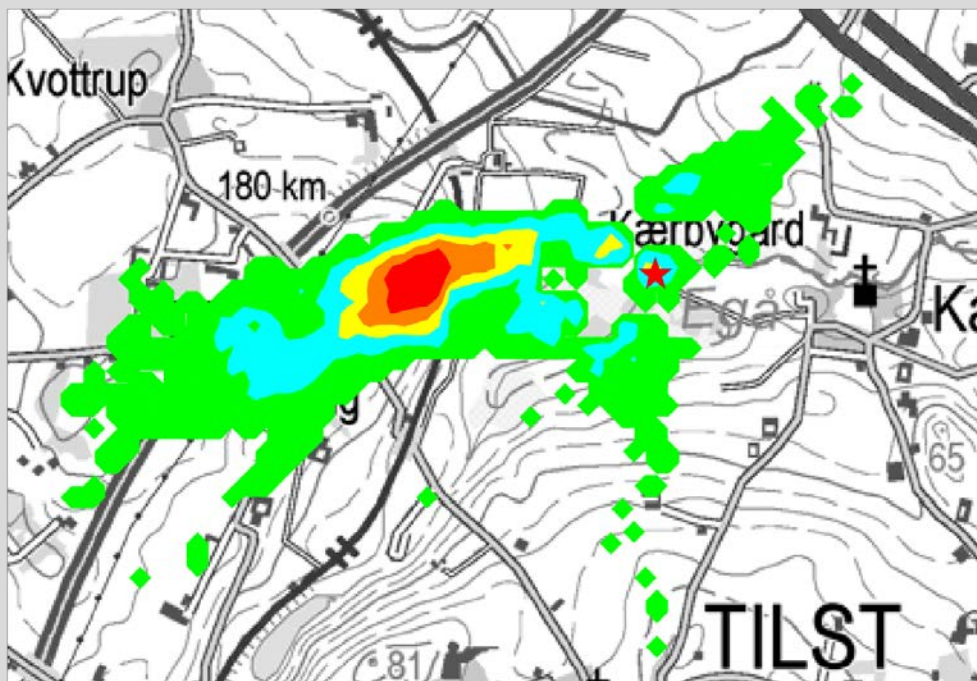


• Reference model  
Catchment probability





# Oplandsusikkerhed

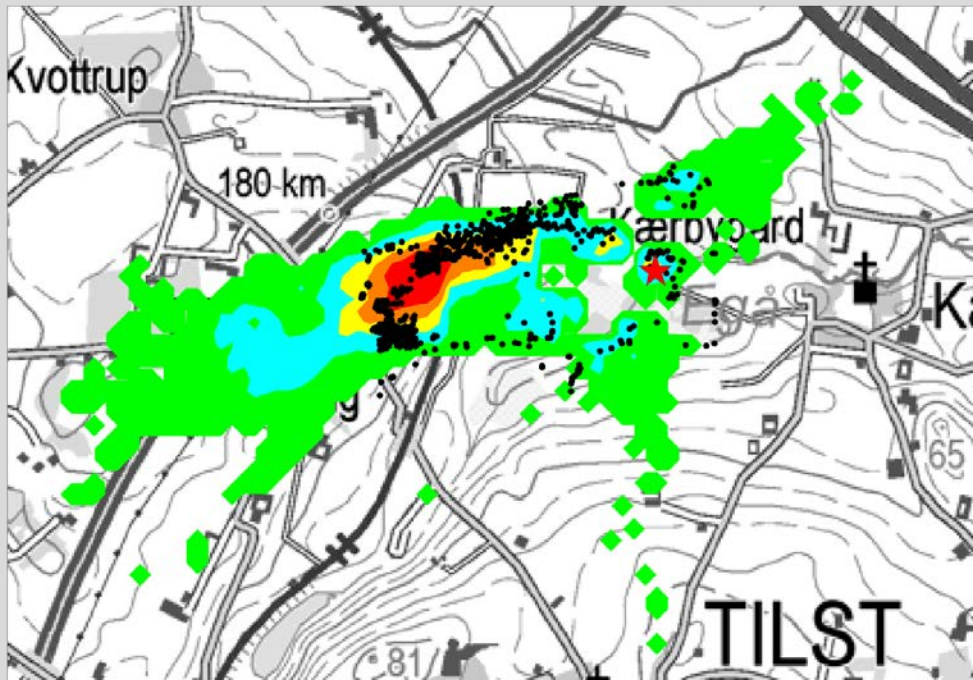


• Reference model

Catchment probability

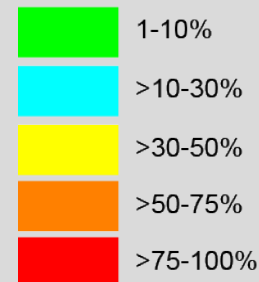


# Oplandsusikkerhed



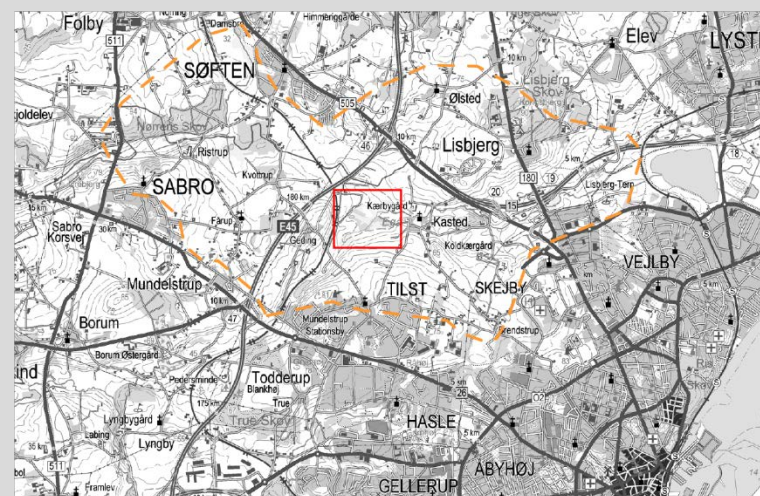
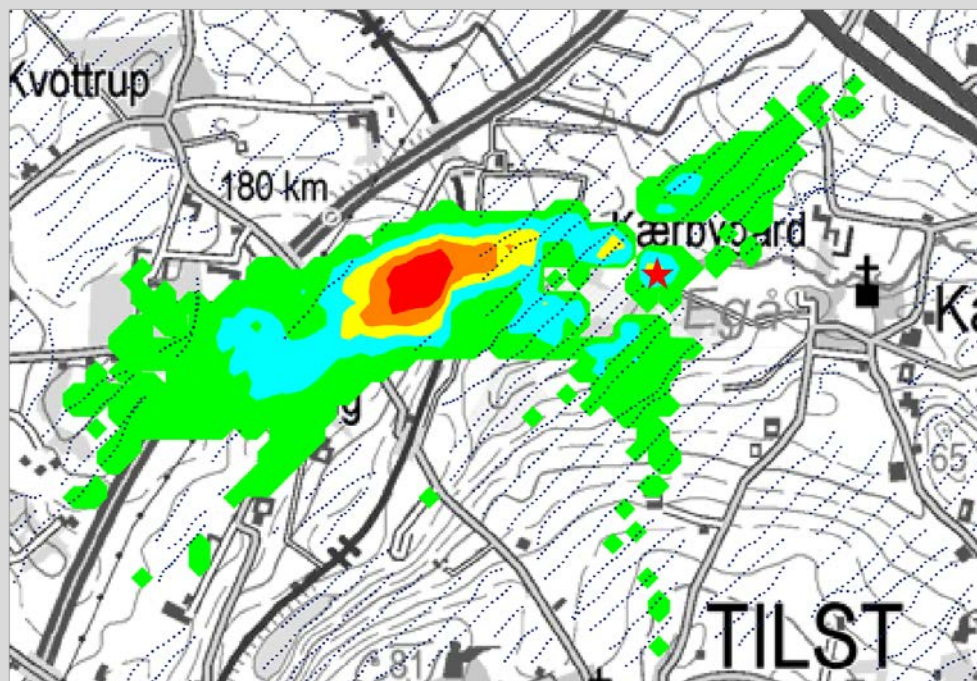
• Reference model

Catchment probability





# Oplandsusikkerhed



• Reference model

Catchment probability



# Opsummering

- **For visse prædiktioner dominerer strukturelle fejl i hydrologiske modeller, men der findes få effektive måder at kvantificerer dem på**
- **Metoden er hurtig og effektiv**
- **Metoden er objektiv og reproducerbar**
- **Vha. subsektion kan vi genererer modeller som overholder alle input data -> geologiske, geofysiske og hydrologiske**
- **Metoden er generisk i forhold til geofysisk input**
- **Vores prædiktion er i overensstemmelse med vores referencemodel**